HOUSE OF COMMONS SESSION 1999–2000

SCIENCE AND TECHNOLOGY COMMITTEE

Second Report

ENGINEERING AND PHYSICAL SCIENCES BASED INNOVATION

Volume I

Report and Proceedings of the Committee

Ordered by The House of Commons *to be printed*
31 January 2000

LONDON: THE STATIONERY OFFICE
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The Science and Technology Committee

The Science and Technology Committee is appointed to examine on behalf of the House of Commons the expenditure, administration and policy of the Office of Science and Technology (and any associated public bodies). Its constitution and powers are set out in House of Commons Standing Order No. 152.

The Committee has a maximum of eleven members, of whom the quorum for any formal proceedings is three. The members of the Committee are appointed by the House and unless discharged remain on the Committee until the next dissolution of Parliament. The present membership of the Committee is as follows:[1]

Dr Michael Clark MP *(Conservative, Rayleigh)*[2]
Mr Nigel Beard MP (*Labour, Bexleyheath and Crayford*)[2]
Mrs Claire Curtis-Thomas MP (*Labour, Crosby*)[2]
Dr Ian Gibson MP (*Labour, Norwich North*)[2]
Mr Robert Jackson MP (*Conservative, Wantage*)[3]
Dr Lynne Jones MP (*Labour, Birmingham Selly Oak*)[2]
Mr Nigel Jones MP (*Liberal Democrat, Cheltenham*)[2]
Dr Ashok Kumar MP (*Labour, Middlesborough South and East Cleveland*)[2]
Mr Ian Taylor MP (*Conservative, Esher and Walton*)[4]
Dr Desmond Turner MP (*Labour, Brighton Kemptown*)[2]
Dr Alan W Williams MP (*Labour, Carmarthen East and Dinefwr*)[2]

On 30 July 1997, the Committee elected Dr Michael Clark as its Chairman.

The Committee has the power to require the submission of written evidence and documents, to examine witnesses, and to make Reports to the House. In the footnotes to this Report, references to oral evidence are indicated by 'Q' followed by the question number, references to the written evidence are indicated by 'Ev' followed by a page number.

The Committee may meet at any time (except when Parliament is prorogued or dissolved) and at any place within the United Kingdom. The Committee may meet concurrently with other committees or sub-committees established under Standing Order No. 152 and with the House's European Scrutiny Committee (or any of its sub-committees) for the purpose of deliberating, taking evidence or considering draft reports. The Committee may exchange documents and evidence with any of these committees, as well as with the House's Public Accounts, Deregulation and Environmental Audit Committees.

The Reports and evidence of the Committee are published by The Stationery Office by Order of the House. All publications of the Committee (including press notices) are on the Internet at www.parliament.uk/commons/selcom/s&thome.htm. A list of Reports of the Committee in the present Parliament is at the end of this volume.

All correspondence should be addressed to The Clerk of the Science and Technology Committee, Committee Office, House of Commons, London SW1A 0AA. The telephone number for general inquiries is: 020 7219 2794; the Committee's e-mail address is: scitechcom@parliament.uk.

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[1] Mrs Caroline Spelman MP (*Conservative, Meriden*) was appointed on 14 July 1997 and discharged on 22 June 1998.
Mr David Atkinson MP (*Conservative, Bournemouth*) was appointed on 14 July 1997 and discharged on 30 November 1998.
Mrs Jacqui Lait MP (*Conservative, Beckenham*) was appointed on 22 June 1998 and discharged on 5 July 1999.

[2] Appointed on 14 July 1997.

[3] Appointed on 5 July 1999.

[4] Appointed on 30 November 1998.

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SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

(a) Successful innovation does not depend on a uniform process or a set approach; it is inherently dynamic and evolutionary. The success of Government policies designed to foster innovation in industry is dependent on a clear understanding of these issues. We commend efforts to further the understanding of innovation and recommend that they continue to attract Government support (paragraph 10).

(b) There is a failure in the UK to appreciate what at Massachusetts Institute of Technology is termed the "dignity of applied knowledge" (paragraph 12).

(c) Not a single witness disputed the maxim that for engineering and physical sciences based industries innovation required a greater focus on the application and development of scientific advances than in the biosciences and that this was the root of the differences between the two in terms of innovatory performance and approach (paragraph 13).

(d) Since 1993 the UK has seen a greater drop in expenditure on R&D as a percentage of gross domestic product than any other G7 nation as growth in gross domestic product has outpaced R&D investment. (Paragraph 17).

(e) We, in common with the majority of our witnesses, conclude that the UK's relatively poor record in innovation in engineering and the physical sciences is not the result of a weakness in the science base. There is plenty of good research being produced in the UK and there are more innovative ideas than are taken up and commercialised by industry. The UK is strong in terms of scientific production but weaker in terms of its application and exploitation (paragraph 22).

(f) We recommend that the Government assumes a greater rôle in supporting development and technology demonstration where the risks are high but the rewards good if the project is successful. We recommend that the Government supports the development of large scale demonstration facilities to allow UK companies better means of carrying out proof of concept research (paragraph 33).

(g) We recommend that the Government scrutinises closely management and marketing strengths in companies seeking investment grants (such as SMART) and, where necessary, consider providing additional support (paragraph 34).

(h) We welcome the Secretary of State's recognition both of the importance of larger corporations in creating an economy characterised by innovation and of the rôle of Government in stimulating them to innovate (paragraph 41).

(i) For scientific and technological advances to be successfully exploited, each one of the components of innovation — research, development, market investigation, manufacturing and commercial launch and the entrepreneurial spirit to bring them together — must be present. The UK's comparatively poor record in innovation in engineering and physical sciences based industries is not the result of weakness in the research base. The failure results from poor translation of research ideas into viable products — weaknesses closer to the market where industry has primary responsibility such as in development, demonstration of a product integrating various technologies, marketing and launch (paragraph 42).

(j) We recommend that the Government seeks harmonisation of trading patterns and systems across the European Union and gives support to a primary market for growth and technology-based companies (paragraph 49).

(k) We recommend that the Enterprise Fund should do more than provide capital; it should be prepared to support enterprises with functions such as recruiting,

management and business development. We shall monitor the implementation and development of this scheme to assess its effectiveness (paragraph 55).

(l) **If the funds invested generate adequate returns, University Challenge will demonstrate to the venture capital community the benefits of investing in technology-based companies and thus draw in further investment. This should be one of its long-term objectives however, the success of the initiative should be measured by the number of new science and technology- based ventures established by universities as a result of the fund (paragraph 56).**

(m) **We recommend that the Business Link network should be charged with assisting small technology-based firms in preparing for venture capital investment (paragraph 57).**

(n) **We recommend that the Regional Development Agencies should assume responsibility for working with local and regional business angel networks and business introduction agencies (paragraph 58).**

(o) **We welcome the introduction of R&D tax credits to support small companies. It will not, however, affect the behaviour of larger companies whose commitment to innovation is just as important. We recommend that the Government should look again at extending this type of tax credit to large companies (paragraph 60).**

(p) **It is important that any system of fiscal incentives is stable from year to year; is focussed on the cost of development, market research, demonstrators and product launch, and that its value is monitored in the long term (paragraph 61).**

(q) **We welcome the changes in the 1998 and 1999 budgets which some witnesses argued would substantially alter the operation of Capital Gains Tax in the favour of entrepreneurs and management teams. We recommend that the Government monitors closely the impact of these changes to ensure their effectiveness in facilitating innovation. It should also monitor closely approaches to taxation and Capital Gains Tax in other member countries of the European Union (paragraph 62).**

(r) **We welcome the Institutes for Enterprise; they are a step in the right direction and we look forward to them playing a more significant rôle in the future (paragraph 63).**

(s) **We recommend that changes in the reward structure for serial entrepreneurs be coupled with widespread publicity regarding successful rôle models and active Government support in marrying together entrepreneurs with the right technology and access to finance (paragraph 64).**

(t) **We welcome the Secretary of State's undertaking to review the legislation on bankruptcy and insolvency to introduce a distinction between responsible entrepreneurs whose businesses have failed and those whose reckless activities have resulted in business failure (paragraph 65).**

(u) **The 1998 Competitiveness White Paper stated that it is not for Government to determine how companies are managed nor to anticipate boardroom decisions. We agree. Government should, however, encourage firms to adopt a long-term approach to market and technological opportunities by spreading best practice in innovation management and drawing attention to the financial and commercial benefits which can derive from technological innovation. Likewise business schools should ensure that the management of science-based innovation is properly covered in their curricula (paragraph 67).**

(v) **Universities must protect their intellectual property appropriately. Methods of protection will, however, vary depending on a range of factors including the nature of the invention. Consideration of intellectual property rights and patenting should**

not be allowed to act as impediments to the flow of knowledge and expertise which is the fuel for innovation (paragraph 72).

(w) **The Government placed strong emphasis on addressing weaknesses in the EU and UK patent systems in *Our Competitive Future*. Its 'IPR Action Plan' includes working towards an EU patenting system which is both affordable and easily enforceable. We welcome these commitments but note that the German Government said that it favoured a move to the US system. These European and international differences need to be reconciled (paragraph 73).**

(x) **Government policy should be focussed upon achieving two equally important goals. First, Government must ensure that there is a strong public sector research and education base, at all levels, to provide industry with leading-edge research and the highly trained staff "which is the life-blood of technology-based industry". Second, Government must provide an economic and fiscal environment that supports those who innovate, and encourages others to improve their innovative performance (paragraph 74).**

(y) **The greatest contribution that Government can make to industrial innovation is by providing a stable economy over the long term which is conducive to innovation, informed risk-taking and change (paragraph 76).**

(z) **We recommend that Government funding for the Teaching Company Scheme should continue to increase gradually up to the time when the level of return starts to fall significantly (paragraph 79).**

(aa) **We acknowledge LINK's effectiveness in strengthening long-term links between industry and the science base but recommend that steps are taken to reduce the bureaucracy of the scheme and to make it more accessible (paragraph 80).**

(bb) **If LINK is to reach its maximum potential, it must be effectively marketed and easily accessible not only to those companies which are already aware of the benefits of collaboration with the research base but more importantly also to those which have no experience of interaction with academia (paragraph 81).**

(cc) **We welcome the Department of Trade and Industry's commitment to the Faraday concept as a means of transferring technology and instituting market orientated development and its announcement of additional funding (paragraph 82).**

(dd) **We have previously called for greater clarification in existing schemes designed to promote interaction between industry and the research base and recommended that consideration be given to the greater use of the successful LINK scheme as an umbrella to reduce confusion. We do so again (paragraph 83).**

(ee) **There is no intrinsic reason why greater interaction with industry should compromise the ability of the research base to meet its own goals. It is, nevertheless, critical that Government policy, in seeking to increase the industrial relevance and take up of the research it performs, should not overlook the science base's diverse rôles. We are adamant that the primary measure of quality in the science, engineering and technology base should be scientific excellence rather than the potential for commercial exploitation (paragraph 84).**

(ff) **The public interest clearly lies in the easiest possible exchange of knowledge between academics and industry. Funding mechanisms such as the Research Assessment Exercise must encourage universities to exploit their intellectual property and foster a collaborative culture in the university sector (paragraph 85).**

(gg) **HEROBIC is, in terms of its funding, too limited to be effective. The creation of HEROBIC, although a welcome sign of intent, will not be able to affect the culture change that both we and the Higher Education Funding Council for England are**

seeking if the research assessment exercise itself continues to undervalue research undertaken in collaboration with industry or research of industrial relevance (paragraph 86).

(hh) **The conflict of opinion between the Chief Scientific Adviser and industrialists over the availability and suitability of science, engineering and technology graduates needs to be reconciled (paragraph 88).**

(ii) **The Government must recognise the need to increase the quality and levels of competence of science, engineering and technology graduates. The onus must then be on industry to seek ways of attracting the highest quality UK graduates in sufficient number into industrial careers (paragraph 89).**

(jj) **The Government should ensure that Regional Development Agencies, in partnership with Local Authorities, are adequately resourced to provide the infrastructure for economic development and the establishment of clusters around local universities (paragraph 90).**

(kk) **We welcome the Government's recognition of the importance of clusters and the changes that have been made to the planning system to promote their development (paragraph 93).**

(ll) **We recommend that one of the objectives of the Ministerial Group should be to understand better the ways in which technology clusters promote innovation (paragraph 94).**

SECOND REPORT

The Science and Technology Committee has agreed to the following Report:—

ENGINEERING AND PHYSICAL SCIENCES BASED INNOVATION

INTRODUCTION

1. Our first inquiry after our appointment in 1997 looked at the report of the National Committee of Inquiry into Higher Education (NCIHE) and the impact that the measures it proposed would have on the research base in higher education institutions. While the scope of that inquiry was deliberately narrow, many witnesses pointed to the crucial rôle that research plays in sustaining the UK's international competitiveness.[1] In the 1993 White Paper, *Realising Our Potential*, the then Government explicitly acknowledged the contribution that the science base could make to wealth creation and industrial competitiveness.[2] Indeed, a 1996 study by the Science Policy Research Unit (SPRU) at Sussex University found that "most of the productivity increases this century have come from our mastery over technology".[3] That study, amongst others, also identified a new understanding "in which there are more specific expectations that basic research should generate economic and social benefits in return for the substantial public funds that it receives."[4] These considerations led us to undertake an inquiry into the ways in which the output of the wider science base, not just that part of it which is represented by higher education, is utilised by industry. Our decision to place special emphasis on engineering and the physical sciences was taken in response to a general perception that these industrial sectors are less successful than, say, the biological sciences, in converting the results of research into innovation.

Conduct of the Inquiry

2. We have sought to build on the work of other select committees which have examined the relationship between the science base and industrial competitiveness in the past. Our own predecessor Committee in the last Parliament considered *The Routes through which the Science Base is Translated into Innovative and Competitive Technology* by focussing on specific sectors.[5] The Science and Technology Committee in the House of Lords reported on *Innovation in the Manufacturing Industry* in 1991 and 1992;[6] and on *The Innovation-Exploitation Barrier* in 1997.[7] We have also benefited from a number of academic and other studies, some of which have become available during our inquiry. The Government White Paper, *Our Competitive Future: Building the Knowledge Driven Economy*,[8] was published as we were in the process of gathering evidence, as was HM Treasury's working group report on the *Financing of High Technology Businesses*,[9] Lord Sainsbury's Report on Biotechnology Clusters,[10] and the Baker Report on *Creating Knowledge Creating Wealth: Realising the Economic Potential of Public Sector Research Establishments*.[11]

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[1]First Report from the Science and Technology Committee, Session 1997-98, on *The Implications of the Dearing Report for the Structure and Funding of University Research*, HC 303-I, March 1998.

[2]*Realising Our Potential*, 1993, Cm. 2250.

[3]SPRU, *The Relationship Between Publicly Funded Basic Research and Economic Performance*, July 1996, p. 54.

[4]*Ibid.*, p. 55. *See also* HC 303–II, Q. 533.

[5]First Report from the Science and Technology Committee, Session 1993-94, on *The Routes through which the Science Base is Translated into Innovative and Competitive Technology*, (hereafter "*Routes*") HC 74-1, April 1994.

[6]First Report from the House of Lords Science and Technology Committee, Session 1990-91, on *Innovation in the Manufacturing Industry*, HL Paper 18-1, January 1991; Fourth Report from the House of Lords Science and Technology Committee, Session 1991-92, on *Innovation in the Manufacturing Industry*, HL Paper 54, March 1992.

[7]Third Report from the House of Lords Science and Technology Committee, Session 1996-97, on *The Innovation-Exploitation Barrier*, HL Paper 62, March 1997.

[8]*Our Competitive Future: Building the Knowledge Driven Economy*, (hereafter "*Our Competitive Future*") The Government's Competitiveness White Paper, December 1998, Cm 4176, p. 5.

[9]HM Treasury, *Financing of Technology Businesses: A Report to the Paymaster General*, November 1998.

[10]*Biotechnology Clusters: Report of the Team led by Lord Sainsbury, Minister for Science*, August 1999.

[11]John Baker, *Creating Knowledge Creating Wealth: Realising the Economic Potential of Public Sector Research Establishments: A Report to the Minister of Science and the Financial Secretary to the Treasury,* August 1999.

3. Our terms of reference were: "to inquire into the manner in which companies in the fields of engineering and physical sciences decide on developing new products and processes and the factors influencing their decisions."

4. We have benefited from the evidence submitted by a wide range of organisations and individuals. In 16 oral evidence sessions we have heard from 20 sets of witnesses whose expertise and insights have been supplemented by 110 written submissions from other sources. We have visited companies, business support organisations and research institutions in the UK, in the USA and Germany and met many individuals who have given invaluable guidance. (Brief synopses of each of those visits appear in annexes to this Report, see pp.xli-xlvii.) We are grateful to all who have assisted us either through oral or written evidence or by less formal means. We would also like to thank our specialist advisers for this inquiry: Professor Derek Burke, former Vice-Chancellor of the University of East Anglia; Professor Michael Elves, former Director of the Office of Scientific and Educational Affairs, Glaxo Wellcome plc; and Professor Michael Brady of the Department of Engineering Science, University of Oxford. We have drawn extensively on these sources of advice and been guided by them in our deliberations. Our conclusions are, however, our own.

Definitions

5. There are many different definitions of 'innovation' in common use. Indeed, it seems that the term is frequently used without any clear understanding of what it actually entails. 'Innovation' is not synonymous with either 'invention' or 'research and development' (R&D), although both can be an integral part of the process. 'Invention' has no implication of application or potential exploitation. 'R&D' can be defined as "Creative work undertaken on a systematic basis in order to increase the stock of knowledge ... and the use of this stock of knowledge to devise new applications" and can be measured against internationally-agreed criteria such as those defined by the Organisation for Economic Cooperation and Development (OECD).[12] Essentially, however, R&D activity is an input whilst innovation is one of the outputs which may result from such activity.

6. Innovation is a process which may span numerous activities. It need not be complicated and can be about incremental changes to products, processes, or management. It can also involve administrative efficiency as much as major scientific developments. In today's global economy, however, with its increasing emphasis on competitive advantage, a greater premium must be placed on the exploitation of scientific and technological advances. One witness told us that "Innovation is taking the bench discovery, matching it either with the market's current needs or potential needs and bringing a <u>successful</u> product to market",[13] implying that new developments had to be commercially successful before they could be classed as innovative. Other witnesses used similar definitions.[14] These definitions have the attraction of simplicity; if a new product is brought to market, its success can be tested. They do however have the disadvantage that innovation cannot be recognised until the process is complete. The Confederation of British Industry (CBI) uses a subtly different definition: "innovation occurs when a new or changed product is introduced to the market, or when a new or changed process is used in commercial production. The innovation process is the combination of activities — such as design, research, market investigations, tooling up, and so on — which are necessary to develop and support an innovative product or production process".[15] Similarly, the OECD state that innovation "consists of all those scientific, technological, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured products, the commercial use of new or improved processes and equipment or the introduction of a new approach to a social service".[16] Our use of the term innovation includes both proven and potential successes.

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[12]Office for National Statistics, *Business Monitor MA14, Research and Development in UK Businesses: Data for 1996*, 1998, p. 5. The "stock" of domestic R&D is calculated as the accumulated sum of past business expenditure on R&D discounted by 5% per annum.

[13]Q.655. (our emphasis)

[14]*See, for example,* Q. 745.

[15]CBI, Innovation Trends Survey 1998.

[16]Organisation for Economic Co-operation and Development, *Frascati Manual.*

7. Innovation is a complex process dependent, among other things, on the science base, industry and appropriate funding. The Office of Science and Technology (OST) is only one of a number of Government departments which influence industry's capacity to innovate. New technologies and scientific advances are largely developed and exploited by industry. Thus we have to look well beyond the OST and the science base to determine the most effective ways to encourage innovation and identify barriers.

The Innovation Process

8. There is a broad consensus that the traditional models of innovation, which place academics pursuing research at one end of the process and companies earning profits at the other, are outdated. Research into innovation and its processes has been conducted for around 40 years, with a rapid growth in activity in the 1960s which coincided with a growth in business-funded R&D. The proportion of innovation which follows the old, "technology push" model is small, although there are specific circumstances where it can happen — particularly where the saleable product is close to the underpinning science, such as can happen in the software and communications industries. These instances are important, as some of the most dynamic and fastest-growing firms in the economy are based directly on emerging technologies. Most researchers and practitioners agree, however, that they do not provide an adequate model for the bulk of innovation in most established companies and particularly not for companies operating in the fields with which we are primarily concerned. Yet, as the Centre for Exploitation of Science and Technology (CEST) argued, there is still "always a danger that debate about physics and engineering innovation in the UK is frustrated by outmoded views on its provenance and how best it is commercialised.".[17]

9. Rather than viewing the innovation process as a progress along a pre-determined, linear path, many of our witnesses saw it as the result of interaction between players — "for example, between industry sectors, between different parts of a supply chain, between academics and scientists, and so on".[18] Recent trends over the last ten years or so show an increasing tendency on the part of companies to engage in alliances with other companies through joint ventures, to sub-contract or out-source business activity, and to increase participation in networks. Much of this activity is directly related to sharing R&D expertise or to the acquisition and development of new technologies; or to acquiring understanding of and access to specialist markets.[19]

10. The Science and Technology Committee in the last Parliament were right to assert that, if Government is to encourage the processes by which innovation takes place, those processes must be fully understood: "policies introduced without understanding will at best be inefficient and at worst counter-productive".[20] Government, industry and the science base must continue to co-operate to broaden understanding of these issues. To give but a single example from many, one of the Economic and Social Research Council's (ESRC) current major research themes is 'Innovation' through which it supports research "to determine the factors that lead to successful innovation and its implementation in public and commercial sectors".[21] It also funds some research units in universities which study innovation in companies. The Department of Trade and Industry (DTI) and OST co-operate with other organisations, notably the CBI, to identify and disseminate best practice, through research and publication on innovation-related topics.[22] Individual researchers are also devoting attention to the study of innovation.[23] **Successful innovation does not depend on a uniform process or a set approach; it is inherently dynamic and evolutionary. The success of Government policies designed to foster innovation in industry is dependent on a clear understanding of these issues. We commend efforts to further the understanding of innovation and recommend that they continue to attract Government support.**

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[17]Ev. p. 277.
[18]Ev. p. 278.
[19]ESRC, *IMI Learning Across Business Sectors: A Background Document*, 1998, para 1.5.
[20]*Routes*, para 46.
[21]Ev. pp. 294-5
[22]*Eg. Research Partnerships between Industry and Universities*, 1994;
[23]Ev. pp. 294-5.

INNOVATION IN ENGINEERING AND THE PHYSICAL SCIENCES BASED INDUSTRIES

11. The distinction we drew at the outset of our inquiry between the UK's performance in innovation in the biosciences and that in engineering and the physical sciences was widely supported by our witnesses. Numerous reasons were put forward to explain the disparity. Professor Richard Brook, the chief executive of the Engineering and Physical Sciences Research Council (EPSRC), told us that in some areas, such as drug discovery, "research yields something which is then readily marketable ... whereas in the engineering and physical sciences ... the distance between the research which has been completed and its eventual place within innovation can be a long, tortuous and difficult one."[24] A similar point was made by Rolls-Royce who told us that innovation in engineering in particular was "much more complex" than in the pharmaceutical sector because its eventual product was the result of integrating and developing numerous different technologies rather than developing a single discovery or advance.[25] Dr David Potter CBE, the chairman and chief executive of Psion plc, told us that in respect of engineering and physical sciences "there is a greater barrier between the application of the science and its implementation in the market".[26] The last DART engine was produced in 1986, but Rolls-Royce will still be making spare parts in 2026. The pharmaceutical industry would not accept this over-simplification however: their development times are invariably long and expensive. The real difference was perhaps best illustrated by Sir Ralph Robbins, the Chairman of Rolls Royce, who, talking of his own company, said "We are different from pharmaceuticals. In many respects they have to do more R than we do and we have to do more D than they do. There is more of a market pull in our business than there is drive from research. That is not to say there is no drive from research but ... pharmaceuticals have to do more blue-sky research. They do not know quite what the market is going to be. The market is generated to a degree by the discoveries.".[27]

12. Others have drawn attention to a reticence on the part of companies to explore the possibilities of exploitation of research that has been conducted in the public sector. This may be due to the lack of market relevance of the research. Some witnesses also made the point that there was a tendency in the UK to value pure science to a greater degree than applied science and therefore that the UK's relative lack of innovation excellence in the engineering and physical sciences fields had cultural causes as well, driven to some degree by funding mechanisms such as the Research Assessment Exercise (RAE).[28] **There is a failure in the UK to appreciate what at Massachusetts Institute of Technology (MIT) is termed the "dignity of applied knowledge".**

13. There are, of course, wide variations in the nature of business within those industries based on engineering and physical sciences. Major process industries, such as aerospace or defence procurement, may recognise long lead times between project specification and delivery. In contrast, as the Engineering Council told us, such product life cycles would be "unbelievable ... in telecommunications".[29] IT-based industries may have as little as six months between project specification and delivery. **Not a single witness disputed the maxim that for engineering and physical sciences based industries innovation required a greater focus on the application and development of scientific advances than in the biosciences and that this was the root of the differences between the two in terms of innovatory performance and approach.**

[24]QQ. 9 and 16.
[25]Q. 134.
[26]Q. 507.
[27]Q. 130.
[28]*See, for example*, Q. 507; Visit to United States.
[29]Q. 371.

THE IMPORTANCE OF INNOVATION

14. Recognition of the importance of innovation to industrial competitiveness has become widespread. The last Science and Technology Committee noted in 1994 that "there is an increasing recognition of the importance of innovation and technology in international competitiveness".[30] Academic study and industrial experience both support the case that innovation can have a fundamental impact on competitiveness. A 1998 study of 15 OECD countries found that "the main factors influencing international competitiveness and growth across countries are technological competitiveness and the ability to compete on delivery".[31] Similarly a separate study found that "Countries which have a large number of industries by international standards in which they have a high rate of innovation tend to experience a systematic appreciation of their currencies over long periods, while less innovative countries witness persistent trade deficits and long-term currency depreciation".[32] As Richard Freeman, Corporate Chief Economist at ICI, has noted, there is now a general consensus that technological change is important for a country's long-term growth.[33] Company chief executive officers serving on the US Council for Competitiveness have identified "gains in product, process and management innovation as the key driving forces" behind the upsurge in US competitiveness since the late 1980s.[34] A survey of UK businesses found that 74% of companies regarded innovation as very important with the remaining 26% regarding it as quite important.[35]

15. Industry has always innovated to succeed: to stay one step ahead of the competition by creating new markets, by anticipating customer needs and by offering new or better products and services. The 16th century scientist and philosopher Sir Francis Bacon, in his essay *Of Innovations*, pointed out that "He that will not apply New Remedies, must expect New Evils: for Time is the greatest Innovator". In the modern economy, however, innovation has become essential not only for commercial success but also for commercial survival. Globalization and the reduction of trade barriers have diluted the concept of a home market and forced major companies, and increasingly small and medium-sized enterprises as well, to compete on an international stage. Falling birth rates and an ageing population mean that economic and tax burdens must be borne by an ever-decreasing proportion of the population. This puts greater pressure on the private sector to increase productivity and on the Government to increase efficiency. More significantly, huge advances in communications and information technologies have accelerated the pace of change. These factors result in an intensifying cycle of competition with profound implications for economic performance and thus for employment and quality of life. Many of our witnesses agreed. Professor Hutchinson of Cranfield University, for instance, told us that, more than ever, industrial growth is dependent on technological change, and IBM, among others, argued that "technology and product innovation are essential to business growth and performance".[36] The Government, too, has repeatedly stated its belief that "innovation is vital to business and wider economic growth".[37] In *Our Competitive Future*, the Government stressed that, in a global economy, where capital is mobile, new technologies spread rapidly and goods can be mass-produced in low cost economies and shipped to developed markets, "our success depends on how well we exploit our most valuable assets: our knowledge, skills and creativity".[38]

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[30] *Routes*, para 30.

[31] J Fagerburg, *International Competitiveness*, Economic Journal, Vol 98, No. 391.

[32] J Cantwell, *Technological Innovation and Multinational Corporations*, 1989.

[33] R Freeman, *Innovation and Foresight*, Office of Science and Technology, 1994, p. 4.

[34] Charles F Larson (Executive Director, US Industrial Research Institute, Inc), *Technological Innovation and Global Competitiveness in the United States*, 1997.

[35] Innovation Advisory Board, *Getting the Message Across: Improving Communication on Innovation between Companies and Investors*, 1993, p. 4 (from a survey conducted by Bain & Co.).

[36] Ev. p. 289.

[37] HM Treasury and Department for Trade and Industry, *Innovating for the Future: Investing in R&D: A Consultation Document*, 1998, para 1.08.

[38] *Our Competitive Future*, p. 5.

SUCCESSFUL INNOVATION

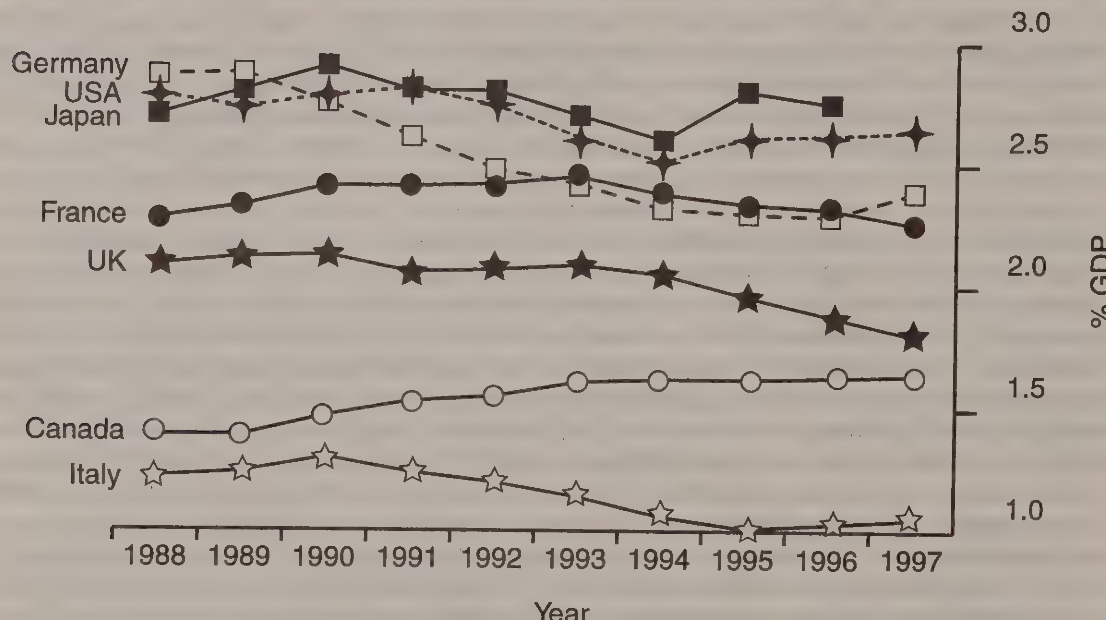
16. Using the definition of innovation that we have already established (see paras 5-7), there is a number of factors that must come together if technological developments are to be turned into successful innovation — research, design and development, market investigation, tooling up and manufacturing process development, and commercial launch. The major part of university and public sector activity is research, directed at acquiring knowledge. The major part of industrial activity is development, directed at achieving what the market wants.

Research

GROSS DOMESTIC EXPENDITURE ON R&D

17. The UK's total spend on R&D has declined in recent years in comparison to other developed nations (see figure 1). **Since 1993 the UK has seen a greater drop in expenditure on R&D as a percentage of gross domestic product (GDP) than any other G7 nation as growth in GDP has outpaced R&D investment.**[39]

Figure 1: R&D Expenditure G7 Countries



Source: The UK R&D Scoreboard 1999.

QUALITY IN THE SCIENCE BASE

18. Industry is not confined to using its own internal R&D as a basis for innovation. It may also draw upon scientific and technological advances and expertise in the publicly-funded science base. The extent and effectiveness of the science base's contribution to the innovation process is, however, dependent on its quality. Measuring the quality of the science base, and the contribution it makes to competitiveness can be as complicated as measurements of innovation. The science base may have many outputs which are used in various, and often unpredictable, ways and often over such long time scales that direct attribution to the science base may be very difficult or impossible. And, as the Royal Society told us, there are "valuable outcomes... such as better-informed decisions regarding product development and commercial strategy, including the identification of ways not to proceed. These outcomes may be particularly valuable ... yet not publicly reported".[40]

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[39] The G7 nations are the USA, the UK, France, Germany, Japan, Italy and Canada.
[40] Ev. p. 388.

19. A DTI report in 1997, using an internationally accepted method of analysis, showed that, with only about 1% of the global population, the UK conducts 5.5% of the world's research, produces 8% of the world's scientific publications and receives 9.1% of all citations.[41] The measure of citations is of particular interest as it gives some indication of the visibility of UK scientific publications although it remains a relatively crude indication of quality. The same study also showed that the UK's science, engineering and technology (SET) base is the most cost effective among G7 countries, as measured by citations per unit of expenditure.[42] The majority of our witnesses agreed that the knowledge output of the science base was of a high quality although many noted that there was room for improvement in dissemination.

20. It is, of course, also important that the UK should be in a position to benefit from the vast amount of scientific research which is performed overseas. One way to ensure that the remaining 94.5% of scientific advances is accessible is through a healthy and diverse SET base, which produces researchers who are welcomed as part of the international research community. These are the people who can understand and bring the fruits of external research to bear on UK activities. Therefore, a strong domestic SET base is the foundation of a virtuous circle which enables the UK to benefit from the totality of the international research effort.

21. Many witnesses stressed the importance of a world class SET base in creating the right infrastructure for successful innovation. The Generics Group, for instance, told us that "without an excellent scientific base, effective technology innovation (and hence product, service and business innovation) is impossible".[43] Nevertheless, it was widely agreed that a good SET base was only one, and not necessarily the most important, among numerous required factors. Dr Alan Rudge, the Chairman of the Engineering Council, told us that "It is development in industry primarily and the quality of management of the company and also the fiscal environment ... plus the regulatory environment, which are important. You have to look at the complete framework rather than at research or research and development".[44] Moreover, it was widely argued that failures to innovate could not be attributed to a lack of scientific and technological developments ripe for exploitation. For instance, British Aerospace[45] stated that "we are not short in the country of people with bright and innovative ideas. The real challenge is creating an environment in which those can come through".[46] Similarly, BT argued that the UK's weaknesses were not the result of a lack of domestic inventiveness, but rather the result of a failure to exploit it.[47] Such comments are supported by hard evidence; there are numerous examples of technologies which have been invented or developed in the UK but which have been successfully exploited overseas. The amorphous silicon technology developed at the University of Dundee, for instance, was commercialised mainly by non-UK companies and is now estimated to underpin 40,000 jobs around the world and the industries which exploit the technology continue to grow.[48]

22. Professor Brook, the chief executive of the EPSRC, and others, also made the point that a failure to exploit commercially the fruits of scientific and technological research was not necessarily just a British problem and that similar sentiments were expressed in almost every other developed nation in the world.[49] Dr Rudge agreed but pointed out that in engineering and the physical sciences in particular, other countries, notably Japan and some of the southern Asian economies, had a better record than the UK. The reason for that was however "not necessarily a science reason, it has more to do with the whole environment within which industry operates. It is more to do with the industrial end.".[50] The health of the UK's research base is an important factor in enabling innovation to take place in industries operating in the fields of engineering and

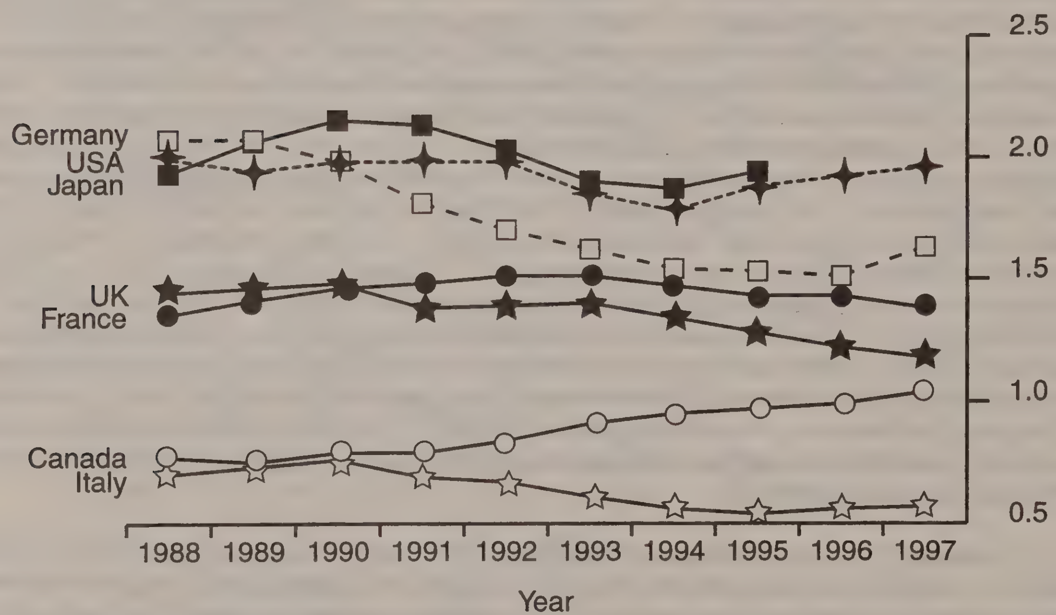
[41]DTI, *Quality of the UK Science Base,* 1997, p. 1.
[42]DTI, *Quality of the UK Science Base,* 1997, p. 1.
[43]Ev. p. 76.
[44]Q. 373.
[45]Now BA Systems.
[46]Q. 615.
[47]Q. 910.
[48]Scottish Enterprise and The Royal Society of Edinburgh, *Technology Ventures: Commercialising Scotland's Science and Technology*, 1996, p. 29.
[49]Q. 8.
[50]Q. 12.

physical sciences. Nevertheless we, **in common with the majority of our witnesses, conclude that the UK's relatively poor record in innovation in engineering and the physical sciences is not the result of a weakness in the science base. There is plenty of good research being produced in the UK and there are more innovative ideas than are taken up and commercialised by industry. The UK is strong in terms of scientific production but weaker in terms of its application and exploitation.**[51] We must therefore look to other parts of the innovation process.

BUSINESS ENTERPRISE RESEARCH AND DEVELOPMENT

23. Business Enterprise Research and Development (BERD) reflects that expenditure incurred by industry and Government in carrying out research and development activities within industrial facilities. In 1970 the UK had a stock of domestic business R&D substantially higher than any other nation except the United States.[52] This has since declined in comparison to major competitor nations and the UK now ranks fifth among the G7 nations in terms of BERD as a percentage of GDP (see figure 2).[53] The fact that BERD financed by firms in the UK has grown more slowly than in other developed nations is only part of the reason for this; there have also been recent declines in R&D performed by industry but financed by Government.

Figure 2: Business Enterprise R&D Expenditure (1988-97)



Source: The UK R&D Scoreboard 1999.

24. Nor has the decline in industry-financed BERD been offset by any increase in expenditure by industry on the research it sponsors in higher education institutions and public sector research institutes. UK industry now funds a smaller proportion of gross domestic expenditure on R&D than any other G5 country (see figure 3).[54] The proportion of gross domestic expenditure on R&D (GERD) funded by UK industry was lower in 1996 than any year since 1986, and remains significantly lower than that in the US, Germany or Japan.

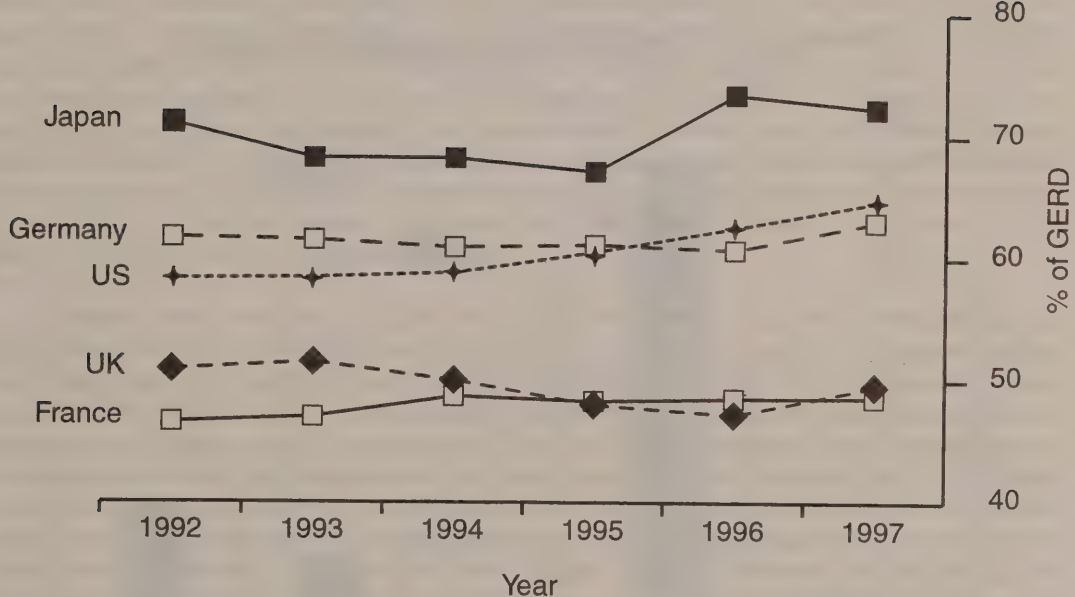
[51] Q.8.

[52] *See* David Coe and Elhanana Helpman, *International R&D Spillovers*, CEPR Discussion Paper No. 840, October 1993. The stock of domestic R&D is calculated as the accumulated sum of past business expenditure on R&D discounted by 5% per annum.

[53] HM Treasury and Department for Trade and Industry, *Innovating for the Future: Investing in R&D: A Consultation Document*, 1998, para 1.14.

[54] The G5 nations are the USA, the UK, France, Germany, and Japan.

Figure 3: GERD Financed by Industry



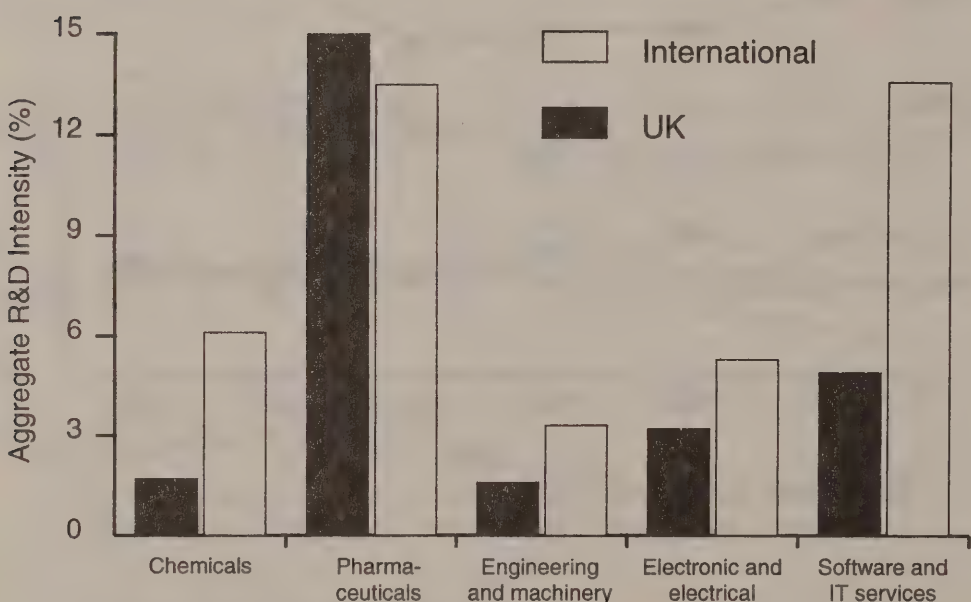
Source: The UK R&D Scoreboard 1999.

25. The picture is not, however, uniform across all sectors of the economy. The UK pharmaceuticals sector, led by major companies such as Glaxo Wellcome, SmithKline Beecham and Astra Zeneca, has consistently invested a higher proportion of turnover in R&D than many of its international competitors.[55] The *1999 R&D Scoreboard* shows, however, that many other sectors are still significantly below the international average for R&D intensity. (R&D Intensity is a measure of the extent to which sales revenues are re-invested in R&D. For companies it is calculated by dividing R&D investment by sales income.) In 1999, the average R&D intensity of the UK's largest chemical companies (in terms of R&D intensity) was less than a third of that of their competitors overseas. In the engineering and machinery, electronic and electrical and software and IT services sectors, the picture is mixed, with some UK companies investing in R&D on a par with their international competitors. However, the aggregate R&D intensity in these sectors is lower than that for international competitors (see figure 4).

[55]Department of Trade and Industry and Company Reporting, *The UK R&D Scoreboard 1998*, p 13.

26. Recent figures also provide a mixed picture on current trends in UK R&D expenditure. The CBI's 1998 *Innovation Trends* survey showed that expenditure on innovation reported by manufacturers fell to 4.9% of turnover in 1997 from 5.9% in 1996, continuing a trend of steady decline from a peak of 6.7% of turnover in 1994. The levels of expenditure reported by non-manufacturers fell more dramatically from 11.8% of turnover in 1996 to 5.4% in 1997 (although this may be explained in part by alterations in the profile of companies responding to the survey). More detailed analysis of the figures from the 1998 *Innovation Trends* survey suggests that overall reported investment in R&D by UK companies is significantly inflated by the activities of a minority of firms which invest heavily in R&D and that the majority of firms actually invest less than the average.[56] Similarly the *1998 R&D Scoreboard* indicates that the overall increases in R&D investment which occurred in 1997 in some sectors (such as engineering and telecommunications) can be accounted for by sizeable increases on the part of a few individual companies.[57] For the 561 UK companies that are listed in the *1999 R&D Scoreboard*, their R&D spend increased by 6% over the previous year. This compares unfavourably with the 12% increase reported by the international companies in the list, which already have a higher baseline investment in R&D. Only 4 UK industry sectors invest 4% or more of their sales income in R&D and only the pharmaceuticals sector invests more than 10%.

Figure 4: UK and International R&D Intensity



Source: The UK R&D Scoreboard 1999.

27. The overall lower R&D intensity of the top UK companies is in part due to the country's industrial profile: a significant proportion of the UK's overall R&D investment takes place in sectors which typically have low R&D intensities. The UK's overall position has, nevertheless, deteriorated over the last decade. This can be attributed to large increases in competitor countries' R&D intensity, coupled with falls in the intensity of some sectors of UK industry, such as metals products, machinery and electrical equipment. These have not been offset by increases in other areas such as healthcare and pharmaceuticals.

28. Despite the mixed picture shown by these statistics there is no doubt that the UK's overall expenditure on business enterprise R&D as a percentage of GDP has declined both absolutely and in comparison with major competitors. Only Germany, which has been adversely affected

[56]CBI, *Technology and Innovation Brief: 1998 Innovation Trends Survey*, June 1998, p. 2.
[57]Department of Trade and Industry and Company Reporting, *The UK R&D Scoreboard 1998*, p 1.

by unification, has performed worse; yet it still devotes a higher proportion of GDP to business enterprise R&D than the UK.

29. A joint study between the DTI and CBI in 1992 found that only one in ten UK companies could be considered to be truly innovative.[58] Despite significant efforts on the part of Government and industry groups since then to promote and encourage innovation, the available data suggest that many UK companies still have a long way to go before they too can be considered truly innovative. One particularly disappointing feature revealed by the *R&D Scoreboard* is the relatively low R&D intensity across the engineering sector compared with certain other UK industrial sectors and, more importantly, with the world average figure for engineering, albeit that world class UK companies in the sector are comparable to the global average. The significance of this is that engineering R&D is largely development.

Demonstration and Development

30. The vast majority of our witnesses agreed that it was in the design and development phase, which is largely undertaken by industry rather than in the public sector, that innovation based on physical sciences and on engineering in particular was at its most different to the equivalent process in the biosciences. Research (R) in the pharmaceutical industry typically accounts for around 30% of a company's total spend on R&D whereas, even in a leading investor in R&D in the engineering sector such as Rolls-Royce, the figure is between 10 and 15%.[59] It is nevertheless a critical part of the process. The Engineering Council, for instance, told us that "there is no doubt that in engineering you do not have a product until you are well into the development phase".[60] In contrast in the pharmaceutical industry, for instance, research can result in the discovery of a molecule that is closer to a marketable product.[61] As Sir Ralph Robbins told us, there is typically a greater emphasis on the development phase in the engineering and physical sciences sectors than in many others.[62]

31. Witnesses drew attention to a number of difficulties associated with development. Dr Rudge, among others, argued that development in most industries was a far more expensive process than research — in many sectors as much as 80-90% of total R&D expenditure were associated with development.[63] In engineering and the physical sciences, as in some others, it can be complex, lengthy, expensive and risky. Other witnesses also made the point that the risks associated with development were higher than those associated with research, not only because of the greater expenditure involved but also because development represented a commitment to a particular product or process.[64] This higher level of risk is often compounded in engineering and the physical sciences by the extended time periods involved between the inception of the project and eventual product delivery. For example over a five year period, Verity plc sunk more than the net worth of the company into a project to develop a new material for loud speakers and into establishing their rights to it around the world.[65] Indeed the risks in the development phase are so high that, as the Engineering Council told us, some companies, and small and medium-sized enterprises (SMEs) in particular, may be unable to undertake development alone and seek assistance or collaboration.[66]

32. One particular aspect of the development phase that witnesses thought particularly problematic was that of the demonstration of applicability of research. Access to incubator facilities can reduce the risk of translation from research to development by allowing proof of concept work to be carried out at an early stage and avoid development which does not result

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[58]Department for Trade and Industry and Confederation of British Industry, *Innovation: the Best Practice: The Report*, 1993, p. 3.

[59]Q. 130. Rolls-Royce spends more on R&D as a percentage of sales than any other engineering company in the UK (see Q. 127).

[60]Q. 367.

[61]Q. 367.

[62]Q. 130.

[63]Q. 14.

[64]QQ.24 and 371.

[65]Q. 73.

[66]Q. 370.

in a marketable product. At the other end of the development process, Rolls-Royce told us that innovation in engineering and physical sciences was "complex in terms of being a system .. We have to take a whole bunch of different technologies, integrate them into a product and the big risk is actually the integration. This is where the technology demonstrator becomes important ... it is the only way that we can decide if research is useful to us". Dr Gordon Edge of Generics plc agreed: "The demonstrations of proof of principle at various stages of development are absolutely essential and it is always worth spending more money on producing multiple examples of a product and it is very dangerous indeed to go straight through" to market.[67] That said, however, the Engineering Council pointed out that it was not always appropriate for those classes of engineering, such as information technology, where speed to market may be more critical.[68]

33. Despite the importance of demonstration and development, some of our witnesses argued that this was often part of the process that was rushed or left out.[69] It is therefore surprising that the vast majority of Government schemes to promote innovation concentrate on stimulating research and technology transfer and conversely that comparatively little is done to support technology demonstration and to encourage greater recognition of the importance of development. The Society of British Aerospace Companies told us that "demonstrators are inadequately funded despite their proven efficacy in reducing project risk and cost".[70] Several witnesses suggested that this was an area where greater Government assistance could make a significant difference to companies, especially those operating in the heavy engineering and chemical sectors or areas where product life cycles are typically long.[71] Other evidence supports their case. British Aerospace pointed to the Government's CARAD programme, which supports technology demonstration in the aerospace industry, as an important risk reduction tool.[72] Nor would such Government support necessarily be a drain on Treasury resources in the long term. In the early 1980s the Government supported the development of Rolls-Royce's Trent engine. Under that deal, because of the project's success, Rolls-Royce now repays £30 million per annum to the Government and will continue to do so for another 50, 60, perhaps a hundred years.[73] Policy in the US is distinctly different in this area, with the Federal Government prepared to put large sums of money behind demonstrator projects — such as the Department of Energy's tens of millions of dollars investment in a consortium of industry and universities which is developing gasoline conversion technology.[74] **We recommend that the Government assumes a greater rôle in supporting development and technology demonstration where the risks are high but the rewards good if the project is successful. We recommend that the Government supports the development of large scale demonstration facilities to allow UK companies better means of carrying out proof of concept research.**

Understanding the Marketplace

34. Sir Ralph Robbins partly attributed Rolls-Royce's success to its ability to recognise where the potential market for its products was, and to access that market: he told us that "The early recognition that we had to export and the early exposure to very demanding markets meant that we realised the product had to move very rapidly ... In my own view that is the reason that we succeeded and people like machine tools and motorcycles did not.".[75] He was among several leading industrialists who argued that "there is more market pull in our business than there is drive from research".[76] This puts a clear emphasis on the need to undertake thorough market investigation: Dr Rudge, for instance, pointed out that the key to innovatory success was matching the market's requirements to the right technology.[77] Many of our witnesses argued,

[67] Q. 339.
[68] QQ. 134-9 and 371.
[69] *See, for example*, QQ. 14 and 371.
[70] Ev. p. 383.
[71] QQ. 479 and 622.
[72] Q. 621.
[73] Q. 149.
[74] Visit to the United States; Q. 207.
[75] Q. 135.
[76] Q. 130; *See also* QQ. 213, 374 and 520.
[77] Q. 371.

however, that the real challenge in industries with long product life cycles was to identify market requirements "in a five, ten or 15 year time frame".[78] 3i Group plc told us "One of the key features here is how unpredictable investing in any of these companies is ... Although the time to market might be quite short, it is quite hard to know when it will appear.".[79] Further, they and others argued, that the unpredictability of rapidly changing markets and the high risks and investment required for development meant that it was essential to have a high level of managerial and marketing expertise and market knowledge which could inform the development process.[80] Several witnesses drew our attention to the increasing requirement by investors in companies to strengthen management and marketing in a like manner. As the Engineering Council put it "The fact is whether you develop the right products very much depends on your marketing expertise.".[81] **We recommend that the Government scrutinises closely management and marketing strengths in companies seeking investment grants (such as SMART) and, where necessary, consider providing additional support.**

35. The advantages of having a clearly identified market and continual customer involvement in the development process are demonstrated in the defence industry. The Defence Evaluation and Research Agency pointed out " the advantage that the defence community has is continuity of a customer base through the development process.".[82] The customer, the Ministry of Defence, sponsors "development from its earlier stages to actual purchase of equipment at the end of the day ... there is a continuity of customer interest [therefore] a fair proportion of what is originally researched does eventually yield a product at the end of the day."[83] The importance of tailoring development work to the needs of the market was further underlined by the Engineering Council which argued that the resources needed to develop a market from scratch to match a new technology were huge.[84]

Process Innovation

36. Several witnesses emphasised the need to be innovative in terms of production and manufacturing processes as well as in the introduction of new products. The Royal Society of Chemistry told us that operational advances were "central to day-to-day business competitiveness".[85] Similarly, British Aerospace stated that in some of its business divisions "as much as half of our research and technology goes into processes, processes for better means of manufacture, better processes for system integration, the development of new tools, new computer tools for example that give us greater efficiency and utilisation".[86] The DTI, too, accept the importance of process innovation in fostering a dynamic, technology-based economy.[87]

Market Launch

37. Placing an innovative product on the market does not alone ensure commercial success. There are many instances where companies which have been first to market a particular product have found others reaping the benefits.[88] Nor can technological superiority guarantee commercial success unless a series of other factors, including effective marketing, are in place. The familiar example of Betamax video recorders is relevant here. By offering a timely and advantageous deal to TV rental companies, VHS video suppliers prevented a technologically superior product, with similar production costs, from achieving any significant, long-term, market share.

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[78]Q. 134.
[79]Q. 167.
[80]*See, for example*, QQ. 374 and 520.
[81]Q. 374.
[82]Q. 70.
[83]Q. 70.
[84]Q. 371.
[85]Ev. p. 50.
[86]Q. 586; *See also* Q. 593.
[87]Ev. p. 164.
[88]Such as the Catscan which was researched and developed by Thorn EMI but later exploited by GE of America.

38. If a product launch is unsuccessful, then all the effort and resources that have been devoted to its development are potentially wasted. Shell UK pointed out that commercial launch could be a particularly high hurdle for SMEs to overcome as they may not have the right range of expertise in-house to ensure success: "it is much harder to get over that bridge and very often an SME has plenty of clever minds, but not enough effort to be able to put into the marketing and obtaining those critical first few contacts and commercialising the ideas".[89] Nevertheless, the majority of Government initiatives, unlike schemes in some other countries, which are designed to stimulate innovation do not extend close enough to market as to offer support for commercialisation.[90]

Large Corporations and Small and Medium-Sized Enterprises

39. Just as the nature of innovation varies across different industrial sectors, so too can the size of a company influence its approach to innovation. As several of our witnesses stressed, it is crucial to distinguish between capabilities of large firms and those of SMEs in the context of innovation strategies.[91] Few SMEs will have the capacity to maintain a central distinct R&D function whereas larger corporations are more likely to have a significant in-house R&D capability.[92] Typically, therefore, SMEs will have to place a greater reliance on access to external information and, "while major multinational enterprises may have access to the necessary skills and specialist facilities worldwide, ... SMEs will be mainly dependent on their availability in the UK".[93]

40. The particular difficulties that SMEs may have in accessing external sources of technological development may be alleviated by Government assistance, delivered through schemes such as the Teaching Company Scheme (TCS) (see para 78), SMART[94] and Faraday Partnerships (see para 82), to focus on encouraging technology transfer between academia and SMEs. The creation and development of SMEs based on high technology must be encouraged. They are important routes for the translation of research into new products and services and can be among the most innovative businesses in the economy. Shell UK told us "SMEs are extremely important ... as a source of creativity and innovation".[95] The contribution that they can make towards creating a buoyant economy which successfully exploits the science base and has innovation at its core is significant, but it should not be over-stated. There is no inherent reason why small firms should be more innovative than larger ones. While their organisational flexibility may be advantageous in that it can make it easier to embrace an innovation culture, this is balanced by disadvantages, notably the unavailability of finance and an inability to devote resources to projects which may only bear fruit in the long term. While growth in small, high technology firms can appear radical and may have a significant impact on employment, it is important to recognise that a 1% increase in the workforce in a company employing 1,000 is the same as a 100% increase in a firm with 10 employees. As Rolls-Royce told us "it is a fact that in many ... areas it is only big companies who can exploit some technology and take it to market".[96]

41. The Secretary of State accepted that Government stimulation of innovation had tended to focus on the rôle of SMEs — "almost assuming... that some of the large companies will look after themselves. I am afraid that is not the case".[97] **We welcome the Secretary of State's recognition both of the importance of larger corporations in creating an economy**

[89] Q. 1076.
[90] *See, for example,* Q. 1077.
[91] *See, for example,* Ev. pp. 51 and 335.
[92] Q. 19.
[93] Ev. p. 292.
[94] SMART is the Small Firms Merit Award For Research and Development. It aims to encourage and facilitate the formation of viable and durable science and technology based businesses by providing early stage investment up to a maximum of £105K.
[95] Q. 1071.
[96] Q. 153.
[97] Q. 1222.

characterised by innovation and of the rôle of Government in stimulating them to innovate.[98]

42. **For scientific and technological advances to be successfully exploited, each one of the components of innovation — research, development, market investigation, manufacturing and commercial launch and the entrepreneurial spirit to bring them together — must be present. The UK's comparatively poor record in innovation in engineering and physical sciences based industries is not the result of weakness in the research base. The failure results from poor translation of research ideas into viable products — weaknesses closer to the market where industry has primary responsibility such as in development, demonstration of a product integrating various technologies, marketing and launch.**

[98]QQ. 1222-3.

CREATING THE CLIMATE FOR INNOVATION

43. However successful industry may be in matching emerging technologies to market requirements many witnesses told us that successful innovation also requires bringing together an exploitable technology with appropriate finance and skilled management and personnel.

Investing in Innovation

44. The UK has a number of strengths and potential strengths regarding the provision of investment finance for innovation. The City of London is a world-class financial centre, the largest in Europe, and has enormous investment funds at its disposal. The domestic venture capital market is the most active in Europe and has invested nearly £23 billion since1983: more than 40% of all European venture capital is invested in the UK.[99] It has, nevertheless, proved difficult to bring together the vitality of the UK's financial markets and the excellence of its science base and a number of authorities, including the Bank of England, have identified an apparent inadequacy of financing as one of the reasons why the UK has failed to match the performance of other countries, and of the US in particular, in commercialising scientific and technological advances.[100]

45. Access to the appropriate level of finance, on the right terms, is important for long-term investment in R&D. Large, established companies will usually fund R&D from retained profits. For them, the main question is often the allocation of resources. For smaller firms, particularly those without a product stream, the problem is more usually one of access to external finance. There is a number of reasons why high technology firms in particular may find this difficult. Technology-based start-ups and spin-outs frequently need external finance at an earlier, and therefore riskier, stage in company development which, coupled with a perception of lower than average returns, deters investors; and, as 3i Group plc told us, the skills required of investors in the sector are higher than average because the markets for products are subject to rapid and unpredictable changes and the companies concerned are typically more volatile.

LARGE COMPANIES

46. There is a general consensus, which was reflected among our witnesses, that many UK companies and financial institutions place too much emphasis on short-term efficiency savings and too little on long-term organic growth;[101] a conclusion which is consistent with the relative decline in industrial expenditure on R&D (see paras 23-29). The availability of funds for R&D and innovation in such companies frequently depends on decisions taken about the allocation of resources between competing needs but where there are insufficient funds internally, even larger companies will have to seek external sources of finance.

Stock Markets

47. The London Stock Exchange has not been as successful as financial markets in the US in promoting high technology stocks. In part this may be due to the different structures of the financial markets in the UK and US. In the US there are, in the main, only two markets — the New York Stock Exchange and NASDAQ[102] — both of which are large and liquid. In contrast in Europe, there are 33 stock exchanges in 18 countries, most of which are very illiquid. NASDAQ in particular has developed into a powerful stock market for growth companies, with a number of notable successes such as Intel and Apple, partly because it set out to specialise in them and partly because of its emphasis on anticipated performance and not just track record which permits a higher level of business risk. Apax Partners told us that NASDAQ "has a clear

[99] HM Treasury, *The Financing of High Technology Business: A Report to the Paymaster General* ("*The Williams Report*"), 1998, para 21(iii).

[100] The Bank of England, *The Financing of Technology Based Small Firms*, 1996.

[101] *See, for example*, QQ. 371 and 495.

[102] NASDAQ was established in 1971 as the National Association of Securities Dealers Automated Quotation. It merged with the American Stock Exchange in 1998.

entrepreneurial identity which appeals to managers of entrepreneurial companies, and so attracts new companies as new technologies evolve".[103]

48. In response to this weakness in the European financial markets, EASDAQ, a European equivalent of NASDAQ which targets growth companies, has been established with the backing of institutional investors, bankers and venture capitalists. We welcome this but it is still early days for EASDAQ and therefore difficult to measure its effectiveness. We note that 3i Group plc's early experiences with EASDAQ have been positive.[104] EASDAQ, however, can only emulate the success of NASDAQ in the States if it can become the primary market of choice for growth and technology-based companies.[105] While there remain multiple markets across Europe, operating within different rules and in different languages, this will be difficult to achieve. **We recommend that the Government seeks harmonisation of trading patterns and systems across the European Union and gives support to a primary market for growth and technology-based companies.**

Technology-Based SMEs

49. High technology SMEs will usually require some source of external finance at start-up or in the early stages of development or both. For the majority of SMEs, bank finance and, in particular, bank loans, provide an important source of initial capital but it is not often the most suitable choice for technology-based companies. High technology start-ups are often perceived to be more risky ventures than start-ups in traditional sectors (although a number of our witnesses challenged the validity of the perception) and the long lead times that can be involved in product development mean that there will be no income in the short-term with which to service loans. The alternative is equity finance which allows the investor to offset the risk against potentially higher than average returns in the long term and avoids cash flow problems for the business.

Venture Capital

50. There has been a huge growth in the volume of venture capital invested in technology-based businesses in the UK in recent years. Figures from the British Venture Capital Association (BVCA) indicate a tenfold increase between 1983 and 1996.[106] Contrary to the experience of the Science and Technology Committee in the last Parliament, many of our witnesses agreed with Oxford Instruments that "ample funding is available for most young companies in high technology".[107] Specialist firms and funds for hi-tech start-ups have been established, such as Amadeus in Cambridge, Merlin Ventures and UK Medical Ventures (which is backed by the Medical Research Council) and major capital investment companies such as 3i Group plc have increased their investments in the technology-based sector. Some high street banks also seem to have responded well to criticisms that they did not offer appropriate facilities for high technology SMEs.

51. Several witnesses argued that, despite recent improvements in the funding available for investment in technology-based companies, there was still a shortage of capital, particularly at the intermediate stage of company development when the investment required was in the region of half a million. According to the BVCA, for example, "the amount of seed capital funding available via the venture capital industry has increased in recent years but still remains the least common type of funding".[108]

52. Much of the growth in venture capital activity can, however, be accounted for by an increasing number of management buy-outs and buy-ins which now make up some 74% of the

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[103]Ev. p. 255.

[104]Q. 194.

[105]We note that NASDAQ has now announced its intention to move into the European market and may well have a significant impact on EASDAQ and other similar national markets.

[106]Ev. p. 268.

[107]Ev. p. 364.

[108]Ev. p. 267. *See also*: Ev. pp. 364 and 267.

total venture capital market.[109] Venture capital for expansion accounts for another 21% of the market which means that only 5% of the available venture capital funds go to start-up finance. In contrast the venture capital industry in the US, as we found on our visit, is more ready to invest in start-ups. In 1997 it invested £5.8 billion in start-ups and early stage companies compared with an equivalent figure of £349 million in the UK.[110] In 1997 UK venture capital investment was around 0.14 % of GDP and much the same in the US.[111] In the US, however, venture capitalists seem more prepared to invest in technology-based companies which account for almost two-thirds of the total.[112] The equivalent figure for the UK is less than a quarter. Moreover, venture capitalists in the US give more assistance to the companies in which they invest, through offering assistance with corporate management or the development of business plans, for instance, than do their UK counterparts. The DTI estimates that efforts by venture capitalists in the US were typically 20% financial assistance and 80% other assistance.

53. There are several reasons why the UK venture capital industry may be cautious over investments in high technology start-ups. The level of return in the short term from seed-corn and early stage investments in high technology companies, generally low anyway, often fails to match predictions made by company management: 3i Group plc told us that 50% of the early stage, high technology firms they invest in underperform against management expectations over the first three years.[113] Further funding is often required to realise returns and therefore investors need to have resources in reserve and the ability to take a long-term view. Our witnesses were, nevertheless, convinced that there were two overriding factors which deter venture capitalists from devoting more seed funds to high technology start-ups. First, the amount of funding sought is often so small that the costs of due diligence and monitoring, which are largely fixed regardless of the size of investment, cannot <u>in their eyes</u> be justified.[114] Secondly, the quality of management in high technology start-ups is frequently not high enough to inspire investor confidence (see paras 62-5).[115]

54. The BVCA suggested that the Government could assist by subsidising the due diligence process.[116] We do not consider that this would be an appropriate response. It would serve to reinforce the false impression that investment in technology-based start-ups does not represent a viable investment for venture capitalists. What is needed is for the venture capital industry to adopt a more long- term approach to its investment strategy, with more of the industry following the example of 3i Group plc. It told us that "We do not believe that the returns from technology investment are unattractive to institutional investors and the returns from our own technology portfolio would support this view. The returns do however come over a relatively long time scale."[117]

55. In December 1998 the Government announced the creation of a national Enterprise Fund in partnership with the private sector.[118] It will provide some £150 million over three years, partly as venture capital for early stage, technology-based businesses and partly through an extension of the existing Small Firms Loan Guarantee Scheme. There is potential here for the Government to act as a rôle model for the venture capital industry. By investing successfully, and linking investments with the provision of management assistance to companies as the US venture capital industry does, it can demonstrate that the sector is worthy of greater attention and effort on the part of the UK venture capital industry as a whole. **We recommend that the Enterprise Fund should do more than provide capital; it should be prepared to support enterprises with functions such as recruiting, management and business development. We shall monitor the implementation and development of this scheme to assess its effectiveness.**

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[109] HM Treasury, *Innovating for the Future: Investing in R&D*, 1998, para 2.17.
[110] *The Williams Report*, para 29. Visit to the United States.
[111] *The Williams Report*, para 2.5.
[112] *R&D Scoreboard 1998*, p. 9.
[113] Ev. p. 251.
[114] *Eg* Q. 505.
[115] *Eg* Ev. p. 268.
[116] Ev. p. 267.
[117] Ev. p. 251.
[118] *Our Competitive Future*, p. 19.

56. We welcome the launch of 'University Challenge' — a £65 million fund which provides early-stage seed funding to help exploit the commercial potential of research by enabling universities and some research institutes to create their own seed-corn funds to support spin-outs from their research. A condition attaching to awards is that the universities must provide 25% of the funding required from other sources. By taking on the larger portion of the risk, the Government can encourage investors to support technology-based companies from their very earliest stages, thus helping to close the gap in seed-corn funding. It will also enable a greater proportion of commercially viable advances to get beyond the proof of concept stage. The potential for success in this sort of scheme was demonstrated during our visit to the Oxford Trust: Oxford University is prepared to encourage proof of concept research, and through the ISIS fund, will provide seed corn funding for these activities. This has resulted in successful spin-out companies such as Oxford Assymetry and Oxford Glycosystems plc. At current funding levels however, University Challenge cannot provide all the seed-corn funds required to commercialise public sector research — nor would it be appropriate for the Government to do so. However, **if the funds invested generate adequate returns, University Challenge will demonstrate to the venture capital community the benefits of investing in technology-based companies and thus draw in further investment. This should be one of its long-term objectives however, the success of the initiative should be measured by the number of new science and technology based ventures established by universities as a result of the fund.**

57. As some small companies do not adequately prepare business plans, the costs of due diligence for the venture capitalist seeking to invest in can be unnecessarily high. The Bank of England, among others, has suggest that 'venture catalysts', i.e. advisers to assist smaller companies, could play an important rôle. We agree. **We recommend that the Business Link network should be charged with assisting small technology-based firms in preparing for venture capital investment.**

Business Angels

58. Many high technology start-ups seek funding from the 'informal' venture capital industry which consists of 'business angels' who are prepared to invest risk capital in small unquoted companies. Business angels tend to invest in smaller amounts than are economic for venture capital funds and therefore can fill the gap between debt finance and formal venture capital investments and are more geared towards investing in early stage and start-up businesses. Both the number of business angel investments and the funds involved have increased dramatically over the last five years. In 1997/98, registered business angels made 227 investments in 223 registered companies, investing a total of £34.6 million — a 28% increase over the previous year.[119] Technology-based firms receive the highest proportion of this investment but, nevertheless, the Bank of England has found that "business angels still appear to play a considerably less prominent rôle in the financing of technology-based firms in the UK than the US".[120] One of the main barriers to greater business angel investment identified by our witnesses, is a lack of information on investment opportunities (this seems generic to all firms rather than specific to the high technology sector). The DTI, with banks and other interested organisations, is supporting the development of a national organisation which is intended to help match business angels to suitable start-up companies. This is a welcome development. Business angels, however, frequently adopt a hands-on approach to their investments and often offer expertise as well as financial assistance and therefore geographical considerations become important. As the Bank of England has stated, business angels "operate most effectively through local networks".[121] Regional Development Agencies should be able to play a valuable rôle in this regard, with their greater knowledge of local economies and regional business networks. **We recommend that the Regional Development Agencies should assume responsibility for working with local and regional business angel networks and business introduction agencies.**

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[119]Bank of England, *Finance for Small Firms: A Sixth Report*, para 5.12.
[120]Bank of England, *Finance for Small Firms: A Sixth Report*, para 5.14.
[121]Bank of England, *Finance for Small Firms: A Sixth Report*, para. 5.14.

Fiscal Incentives for R&D

59. Governments in many parts of the world supplement national private sector investment in R&D by funding R&D directly through grants. Another possible mechanism available to Governments to increase national R&D efforts is to reduce the costs associated with it by providing tax relief or other rebates on R&D expenditure.

60. In its Report on *The Routes Through Which the Science Base is Translated into Innovative and Competitive Technology*, the Science and Technology Committee in the last Parliament made a convincing argument in favour of the introduction of fiscal incentives for R&D. Basing its position on contemporary studies and analysis of the US experience (which has operated a tax system designed to reward increases in R&D expenditure since 1981), it argued that "introducing a tax incentive to increase R&D by 0.1 per cent of GDP pa for five years could increase the rate of growth of GDP by 0.8 per cent pa from the fifth year" and that "the tax yield from the increased incomes would quickly exceed the tax loss from the tax credit".[122] Its recommendations were rejected by the then Government. However, the present Government has announced the introduction of a volume based tax credit for SMEs which will increase the existing 100% relief for R&D expenditure to 150%. Together with existing measures, this will mean that the costs associated with R&D will be reduced by 30% for companies paying tax at the small companies rate. Further, recognising the constraints on early stage companies, the relief will be extended to those companies not yet generating a taxable profit which will be able to take advantage of the relief in advance. **We welcome the introduction of R&D tax credits to support small companies. It will not, however, affect the behaviour of larger companies whose commitment to innovation is just as important. We recommend that the Government should look again at extending this type of tax credit to large companies.**

61. International experience has shown that fiscal incentives may not reach their full impact for some years. The ability of companies to alter their spending patterns on R&D in the short term is quite limited. A study by the Institute of Fiscal Studies has shown that in other countries where tax credits for R&D have been used, the increase in R&D expenditure in the first two years reached only around 10% of the tax forgone by the Government.[123] After five to ten years, however, the increase in R&D expenditure rises to around the same level as the tax forgone, as companies have had the time to respond to new market signals. **It is important that any system of fiscal incentives is stable from year to year; is focused on the cost of development, market research, demonstrators and product launch, and that its value is monitored in the long term.**

Managing Innovation and Entrepreneurship

CREATING SERIAL ENTREPRENEURS

62. The BVCA told us that "the whole debate about providing finance to support technology has tended to miss one crucial point: it is that people are supported by the investment community rather than technology". Many other witnesses made similar points and our attention was repeatedly drawn to "a shortage of seasoned managers who have the capability of building successful businesses".[124] This is consistent with evidence from a survey which found that only 7 per cent of undergraduates in the UK would consider starting their own business compared to 68 per cent in the US.[125] Many witnesses argued that to increase the pool of entrepreneurial talent in the UK, fundamental changes were required in the associated risk and reward structure. A career in an established company usually offers salary progression and relative job security. Taking on a technology-based start-up or emerging company is inherently more risky. Anecdotal evidence also suggests that to do so is less socially acceptable in the UK than in many other countries.[126] Therefore, to encourage both young people embarking on a career and

[122] *Routes*, para 184.
[123] POST, *Innovation From the Science and Engineering Base*, 1998, p. 12.
[124] Ev. p. 268.
[125] Q. 1196.
[126] Q. 175.

seasoned corporate middle managers, with their accumulated experience and expertise, to become entrepreneurs, the potential rewards have to be high enough to overcome these disincentives. Regardless of specific incentives, gains from companies are usually taken as capital and consequently Capital Gains Tax has a major influence. Therefore, **we welcome the changes in the 1998 and 1999 budgets which some witnesses argued would substantially alter the operation of Capital Gains Tax in the favour of entrepreneurs and management teams. We recommend that the Government monitors closely the impact of these changes to ensure their effectiveness in facilitating innovation. It should also monitor closely approaches to taxation and Capital Gains Tax in other member countries of the European Union.**

63. The DTI has provided funding for the establishment of Institutes of Enterprise (based on the model of the Centre for Enterprise at MIT) at eight UK universities which it hopes will play a part in injecting an entrepreneurial spirit into students and academics alike by increasing their exposure to the business world. **We welcome the Institutes for Enterprise; they are a step in the right direction and we look forward to them playing a more significant rôle in the future.**

64. **We recommend that changes in the reward structure for serial entrepreneurs be coupled with widespread publicity regarding successful rôle models and active Government support in marrying together entrepreneurs with the right technology and access to finance.**

65. The high level of stigma associated with business failure in the UK is also a factor in discouraging risk-taking on the part of company managers.[127] In the US a business failure is often seen as a valuable part of an entrepreneur's experience. In contrast, in the UK a single business failure attracts a social stigma which is reinforced by an unforgiving financial community and bankruptcy and insolvency laws which do not distinguish between the responsible risk-taker and the reckless exploiter. **We welcome the Secretary of State's undertaking to review the legislation on bankruptcy and insolvency to introduce a distinction between responsible entrepreneurs whose businesses have failed and those whose reckless activities have resulted in business failure.**

Corporate Management

66. Adopting the right approach to innovation is as important in large, established companies as it is for SMEs and start-ups. A series of surveys, bench-marking exercises and case studies has shown that successful innovation requires the development of a corporate culture in which new ideas flourish and employees are motivated to take responsible risks.[128] We were particularly impressed by British Aerospace, whose strategic commitment to innovation is defined in its mission statement and demonstrated by its activities. Each section of the business builds innovation into its annual business plan; awards are given to innovative employees; and management practices are tested for their impact on innovation. Its commitment to facilitating innovation is underlined by its 'virtual university' — "a business strategy built upon strategic partnerships with academe and enterprise"— which is intended to prepare employees for "the challenges and market evolution which lie ahead" by providing training and development in co-operation with existing universities and by spreading best practice and innovative ideas.[129] Nevertheless, as British Aerospace accepted, an innovation culture "is a very difficult thing to institutionalise ...you cannot .. set up an innovation committee and have it perform".[130]

67. **The 1998 Competitiveness White Paper stated that it is not for Government to determine how companies are managed nor to anticipate boardroom decisions.[131] We agree. Government should, however, encourage firms to adopt a long-term approach to**

[127]Ev. p. 267.
[128]HM Treasury, *Innovating for the Future: Investing in R&D*, March 1998, p. 31.
[129]Ev. p. 264.
[130]Q. 594.
[131]*Our Competitive Future*, para 1.15.

market and technological opportunities by spreading best practice in innovation management and drawing attention to the financial and commercial benefits which can derive from technological innovation. Likewise business schools should ensure that the management of science-based innovation is properly covered in their curricula.

Intellectual Property Rights (IPR)

68. The protection of intellectual property is an important part of the process of innovation.[132] As Shell UK told us "there is limited value in investing heavily in R&D into processes and products if the results are not protected either through immediate commercialisation or longer term through patenting".[133] Through effective technology management, companies can derive competitive advantage by increasing profit margins or by delaying the entry of competitors to markets. There is also potential for revenue generation by a company licensing its under-exploited intellectual property to others.

Universities and the Exploitation of IPR

69. Most universities in the UK maintain their right to the intellectual property developed by staff and students. In many cases there are arrangements for sharing revenue with the inventor, although the proportion assigned varies considerably. In this regard, Cambridge University is an exception "Unlike almost all other universities, Cambridge University does not claim title to the intellectual property created by its employees in the course of their duties. In practice, research in the University is largely funded by the Research Councils, charities and industry, all of which external sponsors require the University to manage the intellectual property output of their funding to the benefit of the inventors and the University".[134] Professor Sir Alec Broers, the Vice Chancellor of Cambridge University, argued that this ethos motivated inventors to exploit research outputs and enabled the University to act as a facilitator "rather than compelling them to work with a potentially heavy-handed bureaucracy".[135] It has been argued that Cambridge's liberal attitude to intellectual property has been a key ingredient in the so-called 'Cambridge phenomenon' which has seen the area become one of the country's foremost hi-tech clusters, although others are less convinced that the system would work as well elsewhere.

70. The University of California ranks highest in the US in terms of gross licence income, receiving some $63 million in 1996.[136] At MIT, which ranks seventh, the annual profit from licensing arrangements is some $9 million.[137] No universities in the UK attain such high figures which might suggest that not enough is done by UK universities to exploit the IPR they hold. We were, however, warned against a straight comparison: at MIT and Harvard, for instance, the income from technology licensing represents some 2% on research income from external sources. At Nottingham University, which has generated £28.5 million in royalties over the last 15 years, the equivalent figure is 10-12%.[138] A university's ability to generate saleable IPR will depend on the research fields in which it is strong. In some instances where the results of the research can also be the final industrial product, the identification and protection of IPR can be relatively straightforward and exploitation on the part of the academic institution may be an attractive option. In many cases, and typically in those industries based on engineering and physical sciences, the path between research and eventual commercial return on exploitation can be lengthy and complex.

71. While protecting intellectual property may be good practice on the part of universities, there can be benefits in flexibility. Over-emphasis on the formal aspects of intellectual property may lead university communities to see the product of their research only as a series of

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[132]Protection can take the form of copyright, registered design, trade or service marks or patents. Patents are the strongest form of protection and the most internationally recognised.

[133]Ev. p. 212.

[134]Ev. p. 224.

[135]Ev. p. 224.

[136]CVCP, *Technology Transfer: The US Experience*, 1999, p. 37.

[137]Visit to the United States.

[138]Q. 1018.

inventions.[139] Such attitudes risk not only distracting Government-funded research from its first objectives of generating knowledge and expertise but also, as the Royal Academy of Engineering argued, "represents an extremely expensive way of making what are often marginal technological advances.".[140]

72. **Universities must protect their intellectual property appropriately. Methods of protection will, however, vary depending on a range of factors including the nature of the invention. Consideration of intellectual property rights and patenting should not be allowed to act as impediments to the flow of knowledge and expertise which is the fuel for innovation.**

Industry and IPR

73. The use of IPR varies widely from sector to sector and company to company. In some sectors, speed to market and the associated know-how are more important.[141] In many industrial fields, however, it is only worthwhile for a company to invest in the development of new products or processes if effective protection for intellectual property is available. Without such rights it would often be impossible for a company to recoup its investment in R&D. It is therefore axiomatic that an effective intellectual property management policy and infrastructure are prerequisites for the development of an innovative economy. We heard a number of criticisms from our witnesses of both the UK and EU patent systems, notably the high cost of initial filings with the EU patent office, (which can exceed £10,000) and the costs associated with defending patents through litigation. **The Government placed strong emphasis on addressing weaknesses in the EU and UK patent systems in *Our Competitive Future*.[142] Its 'IPR Action Plan' includes working towards an EU patenting system which is both affordable and easily enforceable. We welcome these commitments but note that the German Government said that it favoured a move to the US system. These European and international differences need to be reconciled.**

The Rôle of Government

74. As many of our witnesses acknowledged, industry carries the prime responsibility for ensuring that innovative and competitive technology is successfully brought to market. For instance the Chemical Industries Association told us that "Many of the factors which influence an industry's innovative performance are ... internal, and individual companies are in a position to do much to help themselves.".[143] Nevertheless, most witnesses agreed that "Government support, whether at national or European level, is essential to foster innovation in industry.".[144] We agree with those witnesses who told us that **Government policy should be focussed upon achieving two equally important goals. First, Government must ensure that there is a strong public sector research and education base, at all levels, to provide industry with leading-edge research and the highly trained staff "which is the life-blood of technology-based industry".[145] Second, Government must provide an economic and fiscal environment that supports those who innovate, and encourages others to improve their innovative performance.**

Stimulating Innovation

75. There are numerous factors which may serve as stimuli to innovation, such as new marketing opportunities or competitive threats.[146] An emerging technology or a scientific advance can itself, in some circumstances, be the stimulus. In the CBI's 1998 *Innovation Trends* survey, most businesses identified customers and competition as the key drivers for innovation.

[139]Ev. pp. 64-5.
[140]Ev. p. 65.
[141]Ev. p. 333.
[142]*Our Competitive Future*, p. 56.
[143]*See also, for example,* Ev. pp. 147-8.
[144]*See also, for example,* Ev. pp. 147-8.
[145]*See also, for example,* Ev. pp. 147-8.
[146]Ev. p. 75.

Government grants and tax concessions scored lowest (see figure 4). Whether this response is an argument for or against extending the range and effectiveness of Government schemes is debatable but other evidence indicates that they are unlikely to be a significant driver for innovation in any circumstances.[147]

76. Nevertheless, there is a rôle for Government in stimulating innovation. Witnesses drew attention to the important part that Government could play as an honest broker, bringing together those with ideas and those with the means to turn those ideas into competitive technology.[148] The proper rôle for Government was widely seen as that of facilitator and enabler rather than an instigator of innovation. Many of our witnesses held the myriad specific schemes designed to stimulate innovation to be of only secondary importance. Most agreed that **the greatest contribution that Government can make to industrial innovation is by providing a stable economy over the long term which is conducive to innovation, informed risk-taking and change.**

THE RÔLE OF THE PUBLICLY FUNDED SET BASE

77. An excellent SET base is a basic requirement for technological innovation. The SET base not only generates new knowledge which can be exploited by industry but can also be a valuable collaborator with industry and commerce in areas of mutual interest to ensure effective technology transfer. Successful scientific and technological research can be exploited by industry to develop both incremental and step change improvements to products and processes and to exploit or create new markets.[149] If industry is to benefit from the advances made in the publicly funded SET base, it must be aware of them and able to see how they are relevant to its needs. Many witnesses also emphasised the rôle of the SET base in the production of technically educated and scientifically trained people as essential to fostering innovation in industry. The Royal Academy of Engineering told us that "the training of a workforce with high quality skills" was one of the main ways in which Government could facilitate industrial innovation.[150] Indeed, the Royal Society of Chemistry argued that the "most important products of Government-funded research are the technically educated and trained people who are recruited into companies and who drive innovation forwards".[151] Many other witnesses made similar points.[152]

Stimulating Interaction between the Publicly-Funded SET base and Industry

78. There is a number of Government and Research Council schemes designed to increase interaction between the SET base and industry, such as Co-operative Awards in Science and Engineering (CASE), the TCS and the LINK scheme, in addition to initiatives taken by individual academic institutions and some companies. The TCS enables graduates to work within industry introducing new technology under the supervision of an academic researcher. The scheme thus covers both training and technology transfer, as well as providing associates with industrial experience which can benefit them whether they remain in industry or return to the academic environment. Projects usually last at least two years and can involve one or more associates. A review of the TCS found that every £1 million of Government investment, enough to cover around 18 projects, generated 58 new jobs, and resulted in £3.6 million of value added, £3 million of exports, £13.3 million turnover, £1.5 million capital expenditure and £200,000 R&D expenditure.[153] Around 80% of associates are offered employment with the host company at the termination of the project — which is particularly impressive as many associates are placed with SMEs which traditionally have not recruited graduates in large numbers .[154] These

[147]CBI, *Technology and Innovation Brief, 1998 Innovation Trends Survey*, June 1998, p. 3.
[148]*Eg* Ev. pp. 147-8 and 345.
[149]*See, for example*, Ev. p. 49.
[150]Ev. p. 62.
[151]Ev. p. 49. *See also* Ev. p. 357.
[152]*See* Ev. pp. 2, 280 and 323.
[153]Ev. p. 168.
[154]Q. 888.

positive findings were supported by many of our witnesses who found the scheme to be generally effective at linking university know-how to industrial application.[155]

79. In *Our Competitive Future,* the Government announced a doubling of its funding for the TCS. Expenditure will increase from around £10 million per annum to £20 million (although we note that this will not necessarily involve a doubling of the number of projects which are expected to rise from some 650 at present to around 1,000 in three to four years time[156]). Nevertheless, even with its doubling, expenditure on the TCS remains small in comparison with other areas of Government support for industry. For instance, £200 million of Government assistance was given to an LG plc project in Gwent which, it is hoped, will create 6,000 long-term jobs.[157] At a cost of around £33,000 per job, that compares unfavourably with average TCS-created jobs costing some £17,000.[158] We accept that there may be a limit to the number of students available to become associates, as there may be to the number of companies able to participate by providing placements and clearly it would be impossible to orchestrate a huge increase in the programme overnight. Nevertheless we have seen no evidence to suggest that funding of £20 million for the TCS will exhaust the potential for the scheme. **We recommend that Government funding for TCS should continue to increase gradually up to the time when the level of return starts to fall significantly.**

80. The LINK programme, designed to promote pre-competitive research, is supported by the Research Councils and a number of Government departments in addition to the DTI. LINK brings together the commercial developers of a technology with academic partners and potential end users. Government funding for the scheme is more than matched by contributions from the private sector and over 50% of companies which now take part in LINK projects are SMEs. We wrote to a sample of current industrial participants in the field of engineering and physical sciences and the vast majority reported that they had found their experience of the scheme broadly positive both in terms of making progress towards their specific objectives for individual projects and in terms of establishing sustainable links between the company and academia, although some were critical of the high levels of bureaucracy involved.[159] RDP Electronics, for instance, told us that it had "learnt that it is very easy to work with a university to explore new technologies and the mutual benefits can be considerable".[160] **We acknowledge LINK's effectiveness in strengthening long-term links between industry and the science base but recommend that steps are taken to reduce the bureaucracy of the scheme and to make it more accessible.**

81. The DTI told us that most of its schemes designed to foster innovation are initially accessed by industry through the national Business Link network. This was not the experience of those LINK participants responding to our questions, the majority of which had first been drawn to the scheme through existing relations with the science base and, in particular, with universities, which suggests to us that in many cases LINK is preaching to the converted. **If LINK is to reach its maximum potential, it must be effectively marketed and easily accessible not only to those companies which are already aware of the benefits of collaboration with the research base but more importantly also to those which have no experience of interaction with academia.**

82. In 1997 the EPSRC launched four pilot 'Faraday Partnerships', modelled on the Fraunhofer Institutes in Germany which provide the physical resources and expertise for industrially-instigated and funded development work. By building on the expertise of existing intermediary organisations, the partnerships are intended to assist companies to communicate their needs to academic researchers, to increase interaction between universities and industry, to increase the awareness in academia of industry's requirements for new technologies and skilled scientists and engineers and to increase the exploitation within industry of the research

[155]*See, for example,* Ev. pp. 300 and 391.
[156]Q. 888.
[157]LG plc is the Korean manufacturing company formerly known as Lucky Goldstar.
[158]Q. 886.
[159]Ev. pp. 260-1; 273; 273-4.7; 361-2; 368-9; 369-70; 370-1.
[160]Ev. p. 370.

undertaken in the SET base. Each partnership encompasses the research requirements of a specific industrial sector — one, for instance, forms a distributive centre for research and technology related to the packaging industry — and therefore adopts a multi-disciplinary approach. The creation of the Faraday Partnerships, particularly for their explicit recognition of the importance of intermediary organisations and the flow of people in the innovation process, was broadly welcomed by our witnesses, although some were critical of the limited nature of the scheme, and in particular of the absence of financial support from the DTI, and questioned whether at initial levels, the Faraday concept could be effective.[161] The DTI has since announced its intention to participate in the Faraday programme by funding four new partnerships for the next four years, which will take the total number to 20 by 2003, and by providing additional funding to the existing partnerships. On 14th September 1999, proposals were invited to set up the first four of these. The EPSRC will provide up to £1 million to each per annum, with the DTI contributing £1.2 million over three years initially.[162] **We welcome the DTI's commitment to the Faraday concept as a means of transferring technology and instituting market orientated development and its announcement of additional funding.**

83. There is a range of Government schemes and initiatives designed to promote collaboration between industry and the research base such as LINK, the TCS, CASE, Realising our Potential Awards, University Challenge, Institutes for Enterprise and SMART. Many of these attract significant contributions from industry. A number of our witnesses found such a large range of separate programmes confusing. While we accept that there are benefits to maintaining distinct programmes which can then be tailored to the specific needs of target collaborators, there is a risk that the effectiveness of Government efforts could be undermined if the companies are deterred from building on the assets of the science base by the complexity of the very initiatives that are intended to encourage them to do so. **We have previously called for greater clarification in existing schemes designed to promote interaction between industry and the research base and recommended that consideration be given to the greater use of the successful LINK scheme as an umbrella to reduce confusion.[163] We do so again.**

84. Industry and the publicly-funded SET base have different raison d'être. Companies exist to generate profits while the SET base exists to educate, to train and through research to increase the sum of human knowledge: "it is vital to get the relationship between the Science Base and industry right".[164] **There is no intrinsic reason why greater interaction with industry should compromise the ability of the research base to meet its own goals. It is, nevertheless, critical that Government policy, in seeking to increase the industrial relevance and take up of the research it performs, should not overlook the science base's diverse rôles. We are adamant that the primary measure of quality in the SET base should be scientific excellence rather than the potential for commercial exploitation.**

Research Funding and the Research Assessment Exercise

85. The amount of research funding granted by the Higher Education Funding Councils (HEFCs) to each university is determined by a formula which takes into account the number of research-active staff and research quality as determined through the periodic research assessment exercise (RAE). The most recent RAE, undertaken in 1996, has been widely criticised for undervaluing collaborative research projects, a point which we have highlighted in an earlier Report,[165] and which was reaffirmed by several witnesses during this inquiry. The University of Warwick Science Park, for instance, told us that "the dysfunctional behaviour of the academic community towards the commercialisation of research" was driven by the RAE which forces universities "to greater concentration on the outputs which generate a good research score".[166] Cranfield University stated "the undue focus of the Research Assessment Exercise on publication in refereed journals ... diverts some of the most able researchers away from

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[161] Ev. pp. 339-40; Ev. p. 324.
[162] Ev. p. 415.
[163] *Implications*, para 102.
[164] *Routes*, para 79.
[165] *Implications*, paras 63-68.
[166] Ev. p. 401.

innovation and into publishable research".[167] As over-enthusiasm to publish research results on the part of academics is a potential barrier to exploitation, some witnesses suggested that the RAE should instead use the number of patents generated to determine research quality.[168] We do not agree. This would drive researchers to seek patents regardless of whether patents can be exploited or whether there are means to do so. **The public interest clearly lies in the easiest possible exchange of knowledge between academics and industry. Funding mechanisms such as the RAE must encourage universities to exploit their intellectual property and foster a collaborative culture in the university sector.**

86. There have been a number of recent initiatives designed to encourage research of industrial relevance in the SET base. *Our Competitive Future* announced the creation of a new reach-out fund to reward universities "for strategies and activities which enhance interaction with business to promote technology and knowledge transfer".[169] The Higher Education Reach Out to Business, Industry and the Community (HEROBIC) fund will target funding to institutions over a four year period and is intended to give an incentive to institutions to respond to the needs of industry. HEFCE hopesthat HEROBIC will "change institutional and academic cultures in order to attach greater value to activities which are relevant to the needs of employers and industry".[170] In 1995-96 the Funding Councils disbursed £779 million of research specific funds to universities, with allocations largely determined on the basis of the RAE. The HEROBIC fund, in its first year, will stand at £10 million, although this will rise to £20 million for 2000-2001 and subsequent years. **HEROBIC is, in terms of its funding, too limited to be effective. The creation of HEROBIC, although a welcome sign of intent, will not be able to affect the culture change that both we and the HEFCE are seeking if the RAE itself continues to undervalue research undertaken in collaboration with industry or research of industrial relevance.**

87. The recently launched 'Institutes for Enterprise' and the 'University Challenge Fund' partially address the need for a sharper focus on research and industry interaction and while both could potentially be drivers for fundamental change in the outlook of those few universities which will be awarded funds, what is needed is a widespread and long-term mechanism to support and facilitate a culture change across a broad spectrum of institutions.

The Supply of Well-Trained Scientists, Technicians and Engineers

88. Many witnesses however also emphasised the importance of the science base's rôle in producing technically and scientifically trained people. The Royal Society of Chemistry, for instance, argued that they were "the most important products of Government-funded research ... who are recruited into companies and drive industrial innovation forwards".[171] The Chief Scientific Adviser has argued that "some 29% of the 25-34 year old age group who hold a higher education qualification in the UK do so in science and engineering ... this is above the mean of 23% for OECD countries. As far as the UK is concerned, there seems to be an adequate output of scientifically trained graduates and post-graduates".[172] This analysis, which focuses on quantity, is in stark contrast to the experience of some companies we spoke to. Several witnesses had concerns over the number of quality, well-trained scientists, engineers and technicians being produced by UK universities and flowing into industry. A similar problem occurs in the US, as communicated to us at MIT. British Aerospace, for instance, told us that it is "having difficulty ... in filling our engineering recruitment quotas from the UK institutions and for the last two or three years have actually been recruiting engineers from across Europe".[173] Hewlett-Packard also reported shortages, particularly in communications and software, and argued that the problem was not so much the quantity of graduates per se but the number of quality graduates.[174] The Institute of Professionals Managers and Specialists (IPMS) told us that "supply and demand

[167]Ev. p. 290.
[168]Ev. p. 401.
[169]*Our Competitive Future,* p. 25.
[170]Ev. p. 309.
[171]*See also, for example,* Ev. p. 62.
[172]DTI, *Quality of the UK Science Base,* 1997, para 50.
[173]Q. 598.
[174]Q. 788.

for scientists is in a 'low level equilibrium' — a slowly sinking balance of weakening effective demand and a remorselessly weakening supply".[175] Figures certainly indicate a decline in the number of personnel engaged in R&D activity both in the public and private sectors (see figure 5). **The conflict of opinion between the Chief Scientific Adviser and industrialists over the availability and suitability of science, engineering and technology graduates needs to be reconciled.**

Total Personnel Engaged on R&D in the UK 1986-96 (full time equivalents)			
	1986	1996	% change
Business	188,000	139,000	-26%
Research Councils	14,000	12,000	-14%
Government Departments	24,000	16,000	-29%
Higher Education Institutions	52,000	47,000[1]	-9%
Private Non-Profit	7,000	5,000	-28%
Total	285,000	218,000	-23%

Figure 5
Source: SET Statistics 1998

[1] Statistics on R&D staff in universities have not been gathered since 1994 and therefore the figure for 1996 only represents those classified as engaged in research.

89. Witnesses also pointed out that many science and engineering graduates pursue careers in other areas which do not necessarily draw directly on their scientific or technical skills and expertise,[176] and argued that this was partly due to poor career prospects and low salaries afforded to scientists and engineers in core science activities in comparison to those in the city or management.[177] This results in a reduction in the numbers attracted to science and engineering courses at universities which then makes it even more difficult for industry to recruit sufficient quantities of high quality UK science and engineering graduates into science and engineering positions. The importance of intermediate skills in the workforce for productivity and for the successful introduction of new technologies has also been demonstrated[178] but there has been an even greater reduction in the number of support staff in science and technology than that which has occurred in graduate scientists and engineers. The number of technicians, laboratory assistants and draughtsmen employed by UK businesses has fallen from 46,000 full time equivalents in 1986 to 32,000 in 1996, a reduction of some 30%.[179] As the Generics Group argued, the vicious circle is completed by industry having to recruit lower calibre staff, less able to drive innovation forward, who do not justify the higher salaries that would be required to attract the brightest and the best. Industry is the ultimate victim of the vicious circle as its ability to innovate is compromised. **The Government must recognise the need to increase the quality and levels of competence of SET graduates. The onus must then be on industry to seek ways of attracting the highest quality UK graduates in sufficient number into industrial careers.**

[175] Ev. p. 340.
[176] *See, for example*, QQ. 725 and 788.
[177] QQ. 323 and 1099.
[178] Andy Green and Hilary Steedman, *Educational Attainment and the Needs of Industry: A Review of Research for Germany, France, Japan, the USA and Britain*, NIESR Report Series No. 5.
[179] Ev. p. 344.

Local Government

90. During our visit to Germany we witnessed the major contribution that local Government could make to creating a climate in which innovative companies could flourish. The technology park at Herzogenrath was just one of a number in the Aachen region which had been established by regional policy-makers keen to reinvigorate the local economy by capitalising on the asset represented by the high number of technically-qualified graduates emerging from the local university. Funds had initially been provided for the park by the State and Federal Governments but latterly the Town Council had also provided funding and now owns the site.[180] Initially the park was inhabited by existing innovative companies, including some well known companies such as Ericsson who were attracted to relocate by the subsidised rents and excellent facilities. Over time, however, the number of spin-outs and start-ups from the local university has increased.[181] Similar projects exist in the UK, but it was made clear to us during our visit that a development on the scale of the technology park at Herzogenrath would not have been possible if the Town Council had not been able to borrow money — a facility that is not open to local authorities in the UK to the same extent. The Secretary of State agreed that local Government policies could influence innovation, telling us that "the use of land and technology locally is absolutely crucial and ... local government has a crucial rôle".[182] **The Government should ensure that Regional Development Agencies, in partnership with Local Authorities, are adequately resourced to provide the infrastructure for economic development and the establishment of clusters around local universities.**

Technology Clusters

91. For a technology cluster to develop, a number of factors need to come together. Clusters are usually centred on a leading research establishment or a large innovative company as sources of spin-out companies. There may be a science park or a business incubator or both to trigger new companies. Finance must be accessible and space available for development. When a number of firms competing in the same industry in the same locality generate a critical mass, more competitors, attracted by the concentration of talent and knowledge, and complementary activities are drawn to the cluster. In the Cambridge area, for instance, the growth of high technology clusters has attracted venture capitalists and various other business support services. Companies brought together by shared interests in local issues and technologies, and prepared to share the risks and opportunities associated with them, can provide a good (CEST called it the best) opportunity to stimulate sectoral innovation.[183] We saw a practical demonstration of this during our visit to the United States: Massachusetts is home to more than two hundred and fifty medical device manufacturers. At one time there was little interaction between the companies involved but following intervention by the state-run Massachusetts Technology Collaborative, which had worked with industry leaders to explore the value of greater association, a formal cluster, known as MassMedic, had been established in 1996. We were told that MassMedic enabled its members to use their strong presence to influence state and local Government policy, to develop strategic alliances and to establish more effective working relationships both between members and with premier teaching hospitals on research projects and clinical trials.[184]

92. One way in which local authorities can have a significant impact on cluster development is through their planning and local business development strategies. In the 1960s in Cambridge, for instance, the local authority allowed the development of high technology companies on green field sites — a key factor in the development of an IT cluster in that area — but efforts to establish a genome cluster in the same area have been hampered by lack of space for development and an unwillingness on the part of local planners to permit further out-of-town development on environmental grounds. The team, led by Lord Sainsbury of Turville, the Minister for Science, which reported on *Biotechnology Clusters* found that planning restrictions

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[180]The total cost of the development was DM 80 million, of which DM 22 million was provided by the Town Council. Herzogenrath has a population of some 44,000 which means that the investment per head was around DM 500, that is c. £175.

[181]Visit to Germany.

[182]Q. 1237.

[183]Ev. p. 275.

[184]Visit to the United States.

"can be a significant barrier to cluster growth" and called for "an innovative planning solution ... which meets the needs of clusters while avoiding unacceptable impacts on sensitive environments".[185]

93. On 9 November 1999, the Deputy Prime Minister announced changes to the planning system to support the growth and development of clusters which will mean that regional plans will have to identify innovative cluster areas and plan for their expansion. Guidance from the Department of the Environment, Transport and the Regions on the importance of clusters will also be included in planning guidance on local plans. It is too early to assess the impact of these changes but **we welcome the Government's recognition of the importance of clusters and the changes that have been made to the planning system to promote their development.**

94. While there is much anecdotal and empirical evidence to demonstrate the effectiveness of clustering in fostering innovation relatively little is known about how clusters function. The ESRC's support for further research in this area is welcome as isolating and replicating the lessons from such 'innovation engines' will be an important part of developing UK competitiveness. On 18 November 1999, Lord Sainsbury of Turville, the Minister for Science, announced the establishment of a cross-departmental Ministerial Group to drive forward work on clusters. **We recommend that one of the objectives of this Group should be to understand better the ways in which technology clusters promote innovation.**

[185] *Biotechnology Clusters, Report of a team led by Lord Sainsbury, Minister for Science*, August 1999, paras 5.15-17.

CONCLUSIONS

95. The premise of our inquiry that bioscience based companies have been far more successful at innovation than those companies based on the physical sciences and engineering was widely supported by witnesses. Likewise, the definition of innovation adopted, which goes beyond R&D and invention to involve the successful presentation and introduction of a new product to a market or a new process to commercial production, is generally accepted. Science based innovation is, therefore, a process combining research, design, development, market investigation, manufacturing process development and commercially launching the product.

96. The difficulty of innovation in the engineering and physical sciences based industries lies in arriving at a clear presentation of what is wanted by the market and the need to combine various technologies to achieve that. By contrast, the pharmaceutical industry depends heavily on research which, when successful, is readily marketable. In other words, engineering and physical sciences based innovation depends on the pull of the market and so upon market understanding, development, manufacturing processes and market launch much more than it does in the pharmaceutical industry.

97. There is no evidence of any shortage of ideas and knowledge emerging from engineering and physical science research in universities or in industry. Indeed, the Government's efforts to encourage innovation have been directed almost exclusively at creating that fertile soil for innovation growth. The quality of the British science base is good. However, there is a need for funds to demonstrate the usefulness of research as a basis for deciding whether development is likely to be worthwhile.

98. The development of that knowledge to a well-designed product, meeting a market need is where the problems arise. This conjunction of technology with market assessment is almost exclusively and essentially the job of industry. It is far more expensive and risky than research. All indications are that it is this part of the process of innovation which is skimped, under-funded and inadequate in engineering and physical science based companies.

99. That position is worsening. Business funded research and development, of which the major part is development, has been growing more slowly than that of other developed nations so that Britain is fifth among the G7 nations in the proportion of GDP business devotes to R&D. Taken as a proportion of company turnover, UK pharmaceutical companies' R&D is slightly higher than the international average at approximately 13% but for engineering and machinery, electronic and electrical, software and IT sectors of industry, the proportion of turnover spent on R&D is between a quarter and a half of spending by international competitors.

100. Government policy in this field has been directed at securing a healthy science, engineering and technology base upon which industrial development can feed and which provides trained and experienced scientists and technologists who can carry their skills into industry. That is, indeed, the proper priority for Government.

101. Other aspects of Government policy have been to secure the transfer of science and technology from academic research to industry, particularly for small and medium-sized companies. That, too, is important. Neither of these aspects of policy will notably improve innovation however if industrial development is not there to pick up the ideas. The inevitable result is an increasing queue of ideas originating in Britain but waiting to be commercialised elsewhere.

102. The Government's tax credit for R&D spending by small and medium-sized companies is directed to encourage more spending on development among those companies. However, if Britain is to remedy its declining capacity for science-based innovation, large companies will play the major part. There is, therefore, a strong case for extending tax credits to them too. Market research and the provision of demonstrators of the final product are recognised as critical to innovative success. It would substantially reduce industry's risks and encourage innovation if the costs of market research, demonstrators and product launch were included in such an R&D tax credit.

103. In engineering and physical science based industries, the failure to innovate sufficiently has resulted from a lack of investment in demonstration, development and marketing — key parts of the innovation process, but parts which are ultimately the responsibility of industry to address. Government support for the innovation process must recognise this rather than concentrate too heavily on the research phase or technology transfer. A fundamental shift in Government policy is required based on the recognition that, first, ultimately only industry can deliver an innovative economy and, secondly, that the science base, although critical to successful innovation, can provide only the first step in what can be a long, complicated, expensive, and risky path between invention and commercial exploitation.

Annex 1: Summary of the Committee's Visit to The Generics Group

Cambridge, 20th May 1998

THE GENERICS GROUP

The Generics Group, founded in 1986, is a major technology and business consulting and investment organisation, with an international reputation for the successful exploitation of emerging science and technology into commercial markets. It employs over 200 staff. The majority of its work is undertaken on behalf of large international companies but it also works with small, start-up companies, many of which are spin-outs from its own organisation.

1. Meetings with Dr Gordon Edge, Executive Chairman, The Generics Group, Dr Peter Hyde, Managing Director, Dr Mike Crossfield, Director, Engineering Division, Mr David Ely, Senior Consultant, Sensors Division, and Mr Mike Reynolds, Consultant, Communications Division, and others, Scientific Generics

   Topics discussed: Cambridge and technology-based companies; intellectual property; start-ups and spin-out companies; fostering a innovative culture in companies; liaison with customers; the importance of developing and maintaining brand recognition; risk aversion in the UK;

2. Meeting with Dr John Haine, Head of Research, Ionica plc (a spin out from Generics plc).

   Topics discussed: The importance of targeting the right market; developments in telecommunications; provision of finance for companies without a product stream.

Annex 2: Summary of the Committee's Visit to The Oxford Trust and Oxford Instruments

Oxford, 10th June 1998

THE OXFORD TRUST

The Oxford Trust encourages the study and application of science and technology. It is an independent foundation and a registered charity. The Trust administers a number of initiatives designed to help start up and small, technology based firms, such as its Innovation Forum which is a network for the exchange of information and know-how between research organisations, technology-based small and medium-sized enterprises and related professional support services in Oxfordshire, as well as company incubators.

1. Meeting with Mr Paul Bradstock, Chief Executive, Dr David Baghurst, Manager, The Innovation Centre, Ms Gillan Pearson, Director of Education, The Oxford Trust, Sir Peter Williams, Chairman, Oxford Instruments, plc and representatives of resident companies.

   Topics discussed: The rôle of The Oxford Trust; the importance of fostering an innovative culture; encouraging company growth through innovation; investing in technology based companies; Oxford BioTech Network; Managing for innovation; Fostering enthusiasm for science and technology.

OXFORD INSTRUMENTS PLC

Oxford Instruments is a publicly quoted high technology company with origins in the University of Oxford. Sales of c. £150 million pa in instrumentation for healthcare, industry and research are supported by a research and development budget in excess of £10 million pa net of additional research contracts. Exports and overseas sales amount to 85% of sales revenue and the company has strong links to the science bases in the UK, the USA, Europe and East Asia.

2. Meeting with Sir Peter Williams, Chairman, and Mr Andrew Mackintosh, Chief Executive, Oxford Instruments plc.

   Topics discussed: The development of Oxford Instruments plc; the importance of investment in research and development to maintain competitiveness; relations with the science base.

3. Meeting with Dr David Hawksworth, Managing Director, Oxford Magnet Technology.

   Topics discussed: The importance of market identification; manufacturing efficiency; product development and innovation.

Annex 3: Summary of the Committee's Visit to The United States[186]

Washington and Boston, 22nd- 26th June 1998

25th June 1998

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

MIT has a well-regarded track record in creating new inventions and in following up with spin-off companies and licensing agreements which turn scientific knowledge into new products and processes. MIT claims that if the companies formed by its faculty and students were added together they would create the twenty-fourth largest economy in the world. It has spun-off some 4,000 companies which currently employ 1.1 million people and had sales of $232 billion per annum.

1. Meeting with Dr David Staelin, Assistant Director, Lincoln Laboratories, Massachusetts Institute of Technology and Professor James Utterback, Professor of Management and Engineering, MIT Sloan School of Management[187]

   Topics discussed: The value of applied research; terms and conditions of employment of faculty members; spin-out companies; Governmental technology assessment.

2. Meeting with Dr Daniel Roos, Associate Dean of Engineering Systems and Former Director of the Center for Technology Transfer and Product Development, MIT

   Topics discussed: The rôle of the Centre for Technology Transfer and Product Development; Key factors in company development and competitiveness; Liaison between researchers and industrialists; research funding; university and industry relations.

3. Meeting with Professor Joel Moses, Provost and former Dean of Engineering, MIT

   Topics discussed: Attracting industry to work with academic institutions; attracting research funding from overseas; the importance of research excellence; fostering spin-outs and start-ups; patenting.

4. Meeting with Professor Daniel Wang, Professor of Chemical Engineering and Director of the Biotechnology Process Engineering Centre, MIT.

   Topics discussed: The rôle of the Biotechnology Process Engineering Centre, its industrial partners and funding mechanisms; The National Science Foundation's Engineering Research Centres.

5. Meeting with Ms Lita Nelson, Director of the Technology Licensing Office, MIT

   Topics discussed: Facilitating technology transfer through technology licensing; generating revenue through technology licensing; capitalising on federally funded research; industrial liaison; international and domestic patenting; supporting spin-out companies.

6. Meeting with Dr Warren Seering, Director of the Center for Innovation in Product Development, MIT

   Topics discussed: Joint academic/industrial ventures and partnerships; the importance of incremental and step change product innovation and associated research; the rôle of the Center's industrial partners; educating engineers in product development.

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[186] The Committee's visit to the United States related to more than one inquiry. Only those parts of the visit relevant to this inquiry are included in this note.

[187] Professor James Utterback was present throughout all the Committee's meetings at Massachusetts Institute of Technology.

26th June 1998

7. Meeting with Dr John VanderSande, Associate Dean of Engineering, MIT

Topics discussed: The management structure of MIT; federal funding for defence related research; the MIT undergraduate programme; attracting students to engineering; tuition fees.

8. Meeting with Professor James Utterback, Professor for Management and Enterprise, MIT Sloan School of Management

Topics discussed: The relationship between manufacturing and engineering; success records for high technology start-ups; the importance of serial entrepreneurs.

MASSACHUSETTS TECHNOLOGY COLLABORATIVE

The Massachusetts Technology Collaborative is an independent public economic development organization established by the State to foster a more favourable environment for the formation and expansion of technology-intensive enterprises. Focussing on technology-intensive enterprises, it seeks to identify and develop economic clusters — small groups of enterprises with strong logical ties to each other and which might benefit by greater communication and collaboration. It works with identified clusters on common concerns and to help bring about collaborative action.

9. Meeting with Mr Joe Alvani and other representatives of Massachusetts Technology Colloborative

Topics discussed: Identifying clusters; the benefits of company collaboration on non-competitive issues; the Government's rôle in the innovation process.

MASSACHUSETTS TECHNOLOGY DEVELOPMENT CORPORATION (MTDC) AND VENTURCOM

MTDC, established with the implicit mission of creating jobs and bridging the capital gap for start-up companies, was endowed with a small investment fund ($10 million) which had grown over the years. Most MTDC finance deals were between $700,000 and $2 million and were made with companies looking for their second round of financing. In return for the investment, MTDC expected to be involved with the management of the company and had a share in the equity. Since 1978 MTDC had invested $38.5 billion in eighty-eight different companies. Returns on the investments flowed back into the fund. For every dollar it invested, MTDC saw a return of $17.5 dollars. MTDC had been self-financing for many years. In 1997 MTDC-assisted companies had employed 8200 people.

VenturCom was established in 1980 by colleagues at MIT. Its aim was to provide tools to software engineers to help them develop software products. MTDC, Intel and Microsoft had recently invested in the company and at the moment it was developing products for Windows engineers. VenturCom had fifty-five employees. Its headquarters were in Boston but it had a worldwide customer base.

10. Meeting with Mr John Hodgman, Director of MTDC, Mr Michael Dexter Smith, President and Chief Executive Officer, VenturCom, and others.

Topics discussed: The rôle of MTDC and its support for start-up companies; VenturCom's experience working with MTDC; intellectual property and the IT industry; the importance of venture capital.

Annex 4: Summary of the Committee's Visit to Germany

Aachen and Bonn, 19th - 21st January 1999

19th January 1999

AACHEN ASSOCIATION FOR INNOVATION AND TECHNOLOGY TRANSFER

Aachen Association for Innovation and Technology Transfer (AGIT) aims to promote technology transfer in the Aachen region and to accelerate the reconstruction process from a coal mining area to a high technology region. It runs two incubators — Aachen Technology Centre and the Medical Engineering Centre — which are funded by local Government, the local Chamber of Industry and Commerce, local savings banks and other bodies. AGIT offers a number of services, including start-up consultancy, business premises, central facilities, collaboration within technology transfer networks, access to finance, technology brokering and advice on relocation of businesses after termination of incubator lease. AGIT also works closely with a wide network of higher education institutions and industry in the region.

1. Meeting with Professor Evershiem, Aachen University and Chairman of the Supervisory Board, AGIT, Herr Bernd Thomas, Chief Executive, AGIT and representatives of resident companies

   Topics discussed: The respective rôles of regional and federal government in economic development; the provision of business incubators; technology transfer; attracting research centres to the area; service provision for start-up companies; the rôle of the local Chamber of Commerce.

FRAUNHOFER INSTITUTE FOR PRODUCTION TECHNOLOGY

The Fraunhofer Institute of Production Technology is part of the national *Fraunhofer-Gesellschaft*, one of Germany's main non-profit-making research and research-funding organisations. The Institute's main activity is the performance of applied research in collaboration with small and medium-sized enterprises. The Institute had a total budget of DM 28 million in 1996, of which 45% came from industry, 30% from public-sector project grants, and 25% institutional funding from the federal and state governments.

2. Meeting with Herr Professor Dr-Ing Manfred Weck and Herr Dr Stefan Nöken, Fraunhofer Institute of Production Technology

   Topics discussed: Collaboration with other research centres; terms and conditions of employment for Institute staff; staff mobility; the rôle of the Fraunhofer Society; collaboration with industry and ownership of research results; research funding.

AACHEN UNIVERSITY OF TECHNOLOGY, INSTITUTE FOR PLASTICS PROCESSING

Aachen University of Technology focuses its teaching and research on engineering sciences (45% of students) and physical sciences (21% of students). It has close connections with regional research institutes and industry. The University had a total budget of DM 1.1 billion in 1997, including some income from external public and private sources of DM 210 million. The Institute for Plastics Processing's priorities include research and development in injection moulding, processing of plastics, fibre composites, moulded part design and materials technology. Technology transfer is a key activity, as is providing suitable training for students to allow them to enter the crafts and trades.

3. Meeting with Dr Harald Zell, Institute For Plastics Processing

   Topics discussed: Industrial involvement in the Institute and the development of its research programme; planning research of relevance to industry; fostering technology transfer.

20th January 1999

TECHNOLOGY PARK, HERZOGENRATH

The Technology Park, Herzogenrath is built on a former coal mining area as part of the regional restructuring effort to counter job losses in the mining industry. It provides business premises and central facility management services at below commercial rates for small, technology-based enterprises.

4. Meeting with Herr Krings, Director Technology Park, Herzogenrath

   Topics discussed: The development of the Technology Park; capitalising on regional assets; the involvement of local and regional Government; service provision to start-up and other resident companies.

JÜLICH RESEARCH CENTRE

The Jülich Research Centre is one of 16 Helmholtz research centres in Germany. The Centre specialises in interdisciplinary research in areas including: medicine, nuclear chemistry, biological information processing, biotechnology, materials and energy technology, plasma physics, reactor safety research, research reactors, systems engineering, technology development and technology assessment, fuels cells, nuclear fusion, solid state research, surface layers and vacuum physics, thin layer and ion research, nuclear physics, and applied mathematics.

5. Meetings with Professor Treusch, Director and Chairman of the Board of Directors, Herr Plattenteich, Head of the Julich Technology Centre, Dr Jaek, Head of Technology Transfer, Professor Treenhaus, Member of the Board and Dr Breuer, Head of the Office of Public Relations, Julich Research Centre

   Topics discussed: The German research system; the rôle of the Helmholtz Society; Technology transfer; Research and the Julich Research Centre.

21st January 1999

THE GERMAN RESEARCH ASSOCIATION

The German Research Association is Germany's main independent research-funding body, responsible for promoting all branches of science and the arts, mainly at universities, by providing research grants on a competitive, peer review basis. Its programmes include the Individual Grants Programme, research fellowships, priority programmes (which may be funded for up to six years), collaborative research centres (which undertake long-term projects), graduate colleges and scientific awards.

6. Meeting with Dr Rhienhard Grunwald, Secretary General, Dr Schnieder, Director, Scientific and International Affairs, and others, German Research Association

   Topics discussed: Research funding; determining research excellence; funding applied research; intellectual property rights.

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

The Federal Ministry of Education and Research is headed by a Minister of Cabinet rank. Its estimated budget for 1998 is DM 14.9 billion. In 1997 is budget was divided as follows: 38% promotion of technology and innovation; 31% further and higher education, including university buildings, higher education programmes and student loans; 18% basic research; and 13% research and development to improve the quality of life.

7. Meeting with Herr Wolf-Michael Catenhausen, Parliamentary Secretary of State and Ministry officials

Topics discussed: Federal Government objectives in funding research; tuition fees; the respective rôles of the Federal and State Governments in education and training; Government support for technology transfer; the Delphi Exercise; training for entrepreneurs; intellectual property rights.

GERMAN NATIONAL AEROSPACE RESEARCH CENTRE

The German National Aerospace Research Centre has its headquarters in Cologne but also has a number of other Institutes and research facilities. Its research priorities include aviation research, aviation technology, robotics, transport research, fluid mechanics, aerodynamics, materials and structural mechanics, communications, space vehicles, exploitation of space flights, involvement in space missions and energy technology.

8. Meeting with Professor Walter Kröll, Chairman of the Board of Directors, Dr Claudia Langowsky, Head of Technology Transfer, Dr Franz Berger, Resident Researcher for Space Science and others, German National Aerospace Research Centre.

Topics discussed: Federal funding for aerospace research; training scientists and engineers; technology transfer; patenting and technology licensing.

GLOSSARY

AURIL	Association for University Research and Industry Links
BERD	Business Enterprise Research and Development
BVCA	British Venture Capital Association
CASE	Comparative Awards in Science and Engineering
CBI	Confederation of British Industry
CEST	Centre for Exploitation of Science and Technology
DTI	Department of Trade and Industry
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
HEFCE	Higher Education Funding Council for England
HEFCs	Higher Education Funding Councils
HEROBIC	Higher Education Reach Out to Business, Industry and Commerce
IPMS	Institute of Professionals Managers and Specialists
IPR	Intellectual Property Rights
MIT	Massachusetts Institute of Technology
NCIHE	National Committee of Inquiry into Higher Education
OECD	Organisation for Economic Corporation and Development
OST	Office of Science and Technology
RAE	Research Assessment Exercise
R&D	Research and Development
SET	Science, Engineering and Technology
SBAC	The Society of British Aerospace Companies
SMEs	Small and Medium-sized Enterprises
SPRU	Science Policy Research Unit
TCS	Teaching Company Scheme

PROCEEDINGS OF THE COMMITTEE RELATING TO THE REPORT

MONDAY 31 JANUARY 2000

Members present:

Dr Michael Clark, in the Chair

Mr Nigel Beard
Dr Ian Gibson
Dr Lynne Jones
Dr Ashok Kumar
Mr Ian Taylor

The Committee deliberated.

Draft Report (Engineering and Physical Sciences Based Innovation), proposed by the Chairman, brought up and read the first time.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 6 read and agreed to.
Paragraph 7 read, amended and agreed to.
Paragraphs 8 to 10 read and agreed to.
Paragraph 11 read, amended and agreed to.
Paragraphs 12 to16 read and agreed to.
Paragraphs 15 and 16 combined (now paragraph 15).
Paragraphs 17 to 22 read and agreed to (now paragraphs 16 to 21).
Paragraph 23 read, amended and agreed to (now paragraph 22).
Paragraphs 24 to 42 read and agreed to (now paragraphs 23 to 41).
Paragraph 43 read, amended and agreed to (now paragraph 42).
Paragraphs 44 to 48 read and agreed to (now paragraphs 43 to 47).
Paragraph 49 read, amended and agreed to (now paragraph 48).
Paragraphs 50 to 62 read and agreed to (now paragraphs 49 to 61).
Paragraph 63 read, amended and agreed to (now paragraph 62).
Paragraphs 64 to 73 read and agreed to (now paragraphs 63 to 72).
Paragraph 74 read, amended and agreed to (now paragraph 73).
Paragraphs 75 to 88 read and agreed to (now paragraphs 74 to 87).
Paragraph 89 read, amended and agreed to (now paragraph 88).
Paragraphs 90 read and agreed to (now paragraph 89).
Paragraph 91 read, amended and agreed to (now paragraph 90).
Paragraphs 92 to 94 read and agreed to (now paragraphs 91 to 93).
Paragraphs 95 to 98 read, amended and agreed to (now paragraphs 94 to 97).
Paragraphs 99 to 104 read and agreed to (now paragraphs 98 to 103).

Annexes 1 to 4 read and agreed to.

Ordered, That a list of abbreviations be annexed to the Report. — (*The Chairman.*)

Resolved, That the Report, as amended, be the Second Report of the Committee to the House.

Ordered, That the Chairman do make the Report to the House.

Ordered, That the provisions of Standing Order No. 134 (Select committees (reports)) be applied to the Report.

Several papers were ordered to be appended to the Minutes of Evidence.

Ordered, That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House. — (*The Chairman.*)

The Committee deliberated.

[Adjourned till Wednesday 2 February at a quarter to Four o'clock.

LIST OF WITNESSES

Wednesday 3 June 1998

THE ENGINEERING COUNCIL

Monday 11 November 1998

BTG PLC

Wednesday 25 November 1998

Wednesday 2 December 1998

BRITISH AEROSPACE PLC

Wednesday 9 December 1998

AEA TECHNOLOGY LTD

HEWLETT-PACKARD LTD

Wednesday 16 December 1998

DEPARTMENT OF TRADE AND INDUSTRY

Wednesday 13 January 1999

BRITISH TELECOMMUNICATIONS PLC

Wednesday 27 January 1999

THE ASSOCIATION FOR UNIVERSITY AND INDUSTRY LINKS (AURIL)

SHELL UK LTD

Wednesday 1 February 1999

UNIVERSITY OF CAMBRIDGE

Wednesday 24 February 1999

THE DEPARTMENT OF TRADE AND INDUSTRY

LIST OF MEMORANDA INCLUDED IN THE MINUTES OF EVIDENCE

LIST OF APPENDICES TO THE MINUTES OF EVIDENCE
VOLUME II

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UNPRINTED MEMORANDA

Additional Memoranda have been received by the following and have been reported to the House, but to save printing costs they have not been printed and copies have been placed in the House of Commons Library where they may be inspected by Members. Other copies are in the Record Office, House of Lords, and are available to the public for inspection. Requests for inspection should be addressed to the Record Office, House of Lords, London, SW1. (Tel 020-7219 3074). Hours of inspection are from 9.30 am to 5.30 pm on Mondays to Fridays.

1. Gatsby Charitable Foundation
2. Appendices to Memorandum submitted by Ms K Marjorie de Reuck
3. Appendices to Memorandum submitted by the Silsoe Research Institute
4. Appendices to Memorandum submitted by the Association of Independent Research and Technology Organisations
5 Annexes to Memorandum submitted by the Construction Research and Innovation Strategy Panel
6. Annex to Memorandum submitted by the TEC National Council
7. Annexes to Memorandum submitted by NatWest Group Innovation and Growth Unit
8. Annex and Appendices to Memorandum submitted by the Institute of Inventors
9. Appendix to Memorandum submitted by Dr Malcolm Skingle
10. Memorandum, Annex, and Appendices submitted by Microsoft Limited
11. Annex to Memorandum submitted by Smiths Industries plc
12. Annex to Memorandum submitted by 3i Group plc
13. Annex to Memorandum submitted by Scottish Software Partners Centre
14. Annex to Memorandum submitted by Bookham Technology
15. Department of Trade and Industry

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Second Report: The Year 2000—Computer Compliance (HC 342)

Third Report: Glaxo Wellcome and Smithkline Beecham: The Merger Proposals (HC 627)

Fourth Report: The Cloning of Animals from Adult Cells (HC 1039)

Fifth Report: British Biotech (HC 888)

Sixth Report: Science and the Comprehensive Spending Review (HC 1040)

First Special Report: The Government's Response to the Committee's Fourth Report, Session 1996–97, The Research Council System: Issues for the Future (HC 302)

Second Special Report: The Government's Response to the Committee's Third Report, Session 1996–97, The Natural Environment Research Council and Research into Climate Change (HC 306)

Third Special Report: The Government's Response to the Committee's First Report, Session 1997–98, The Implications of the Dearing Report for the Structure and Funding of University Research (HC 799)

Fourth Special Report: The Government's Response to the Committee's Fifth Report, Session 1997–98, British Biotech (HC 1185)

Session 1998–99

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Second Report: The National Endowment for Science, Technology and the Arts (HC 472)

Third Report: The Scientific Advisory System: Mobile Phones and Health (HC 489)

Fourth Report: The Regulation of the Biotechnology Industry (HC 535)

First Special Report: The Government's Response to the Committee's Sixth Report, Session 1997–98, Science and the Comprehensive Spending Review (HC 234)

Second Special Report: The Government's Response to the Committee's Second Report, The National Endowment for Science, Technology and the Arts (HC 822)

Session 1999–2000

First Report: The Year 2000—Computer Compliance: Follow-Up (HC 535)

Printed in the United Kingdom by The Stationery Office Limited
2/00 484152 19585 CRC Supplied

ISBN 0-10-210600-2

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